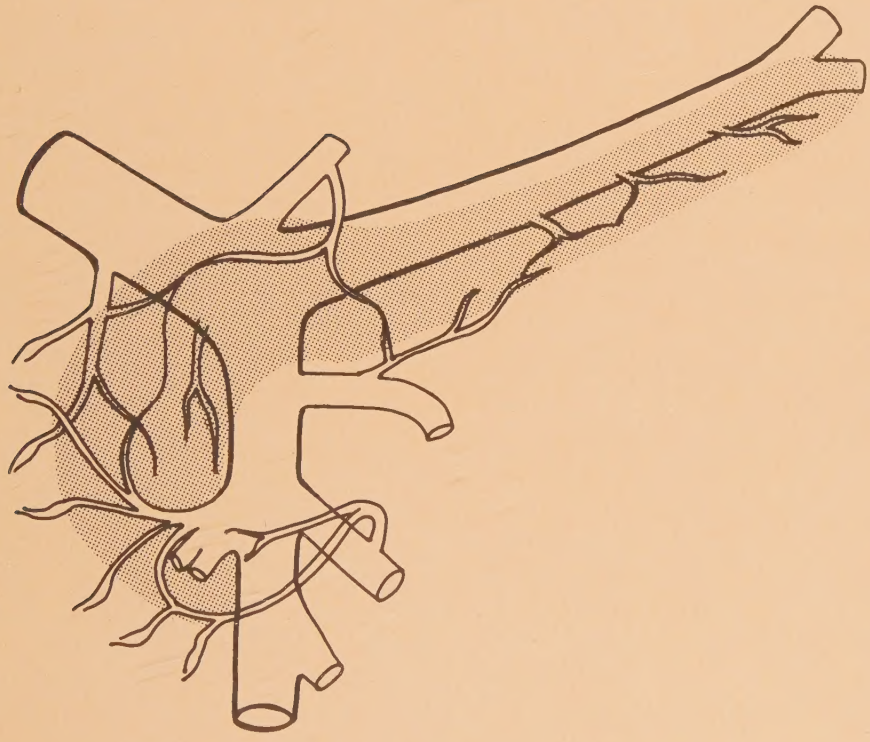
PHLEBOGRAPHY OF THE PANCREAS

Anatomy, Technique, and Clinical Applications

Wolfgang Reichardt



Lund 1979

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Anatomy, Technique, and Clinical Applications

av

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Akademisk avhandling som med vederbörligt tillstånd av Medicinska Fakulteten vid Universitetet i Lund för avläggande av medicine doktorsexamen kommer att offentligen försvaras i Föreläsningssal 3, Centralblocket, Lasarettet i Lund, fredagen den 14 december 1979, kl 09 15

Organisation
LUND UNIVERSITY
Department of Diagnostic Radiology
University Hospital
S-221 85 Lund, Sweden

Document name
DOCTORAL DISSERTATION

Date of issue
December 1979

CODEN:
LUMEDW/(MEXL-1004)/01-62/1979

Author(s)
Wolfgang Reichardt

Sponsoring organisation

Title and subtitle

Phlebography of the pancreas. Anatomy, Technique, and Clinical Applications

A4 A5

Abstract

The roentgen anatomy of the pancreatic veins was examined by injection of a solidifying contrast material into the portal venous system of 22 human cadavers. After dissection the venous anatomy of the pancreaticoduodenal specimens was documented by radiographs. Based on 148 clinical selective phlebographies the normal appearance of phlebography of the head, the body, and the tail of the pancreas was described.
Selective catheterization of the pancreatic veins for blood sampling and hormone assay was performed in 16 patients with endocrine tumours of the pancreas or islet cell hyperplasia. The technique of selective catheterization was described in detail. The accuracy of this method to localize endocrine lesions was compared to angiography, and found to be higher. Selective phlebography of the pancreatic veins was useful for detection of anomalous venous drainage and to document the site of blood sampling.
The phlebographic findings in 67 patients with proven diseases in the region of the pancreas were analysed. Differentiation between chronic pancreatitis and pancreatic carcinoma larger than 3 cm in diameter was found to be possible. The clinical value of the method was discussed.
In 33 patients with pancreatic carcinoma the findings at percutaneous transhepatic portography and selective phlebography were correlated with those of angiography regarding prediction of resectability. Portography was found to be useful in cases in which angiography did not give unequivocal information about non-resectability of the tumours.

Key words A4 A5

Pancreatic phlebography, Catheterization technique, Venous anatomy, Angiography, Islet cell tumours, Pancreatic carcinoma.

Classification system and/or index terms (if any)

Supplementary bibliographical information

Language
English

ISSN and key title

ISBN

Recipient's notes

Number of pages
62

Price

Security classification

DOKUMENTDATABLAD enl SIS 61 41 21

Distribution by (name and address)
Dr Wolfgang Reichardt, Department of Diagnostic Radiology, University Hospital, S-221 85 Lund, Sweden

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PHLEBOGRAPHY OF THE PANCREAS

Anatomy, Technique, and Clinical Applications

W O L F G A N G R E I C H A R D T

Lund 1979

os Reprotryck i Malmö AB, 1979

This thesis is based on the following papers:

I. W. Reichardt and R. Cameron: Anatomy of the pancreatic veins. A post mortem and clinical phlebographic investigation. To be published in Acta Radiol Diagn (1980).

II. W. Reichardt and S. Ingemansson: Selective vein catheterization for hormone assay in endocrine tumours of the pancreas. Technique and results. To be published in Acta Radiol Diagn (1980).

III. W. Reichardt: Selective phlebography in pancreatic and peripancreatic disease. To be published in Acta Radiol Diagn (1980).

IV. W. Reichardt and I. Ihse: Percutaneous transhepatic portography in pancreatic carcinoma. Diagnosis and evaluation of resectability. To be published in Acta Radiol Diagn (1980).

Reference to these papers will be made by the numerals I - IV.

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II. Selective vein catheterization for hormone assay in endocrine tumours of the pancreas. Technique and results.

III. Selective phlebography in pancreatic and peripancreatic disease.

IV. Percutaneous transhepatic portography in pancreatic carcinoma. Diagnosis and evaluation of resectability.

INTRODUCTION

Examination of the venous drainage of organs for morphological evaluation and blood sampling to localize endocrine disturbances has been well established for years but the technique has not been applied to the pancreas. The reason for this exception was the difficult approach to the pancreatic veins. Performing transumbilical portography for examination of the parenchyma of the liver, GÖTHLIN et coll (1974) accidentally found the pancreatic veins to be available for selective catheterization. Using the percutaneous transhepatic access to the portal vein selective catheterization of portal vein tributaries was less complicated. Therefore this approach was used in patients examined for blood sampling in endocrine tumours of the pancreas (LUNDERQUIST et coll 1978 b), and intestine (REICHARDT et coll 1979a) and in patients with bleeding oesophageal varices for obliteration of the coronary vein (LUNDERQUIST et coll 1978 a). The third possible route to catheterize the pancreatic veins - the transjugular transhepatic puncture of the portal vein - has so far only been used in an experimental study in dogs (RÖSCH & DOTTER 1975).

It has been demonstrated that localization of insulin-, glucagon-, gastrin-, and serotonin-producing tumours of the pancreas by arteriovenous hormone gradients is possible (INGEMANSSON et coll 1977 a, b, 1978; REICHARDT et coll 1979 a, b). The method is also sensitive enough to localize islet cell hyperplasia (INGEMANSSON et coll 1977c).

Recent reports (TURNER et coll 1978; GARDNER et coll 1979; FELTRIN et coll 1979) have further indicated that catheterization of pancreatic veins for blood sampling in patients with endocrine tumours can be accepted as a useful method for localization.

Detailed knowledge of pancreatic venous anatomy including its anomalies is essential for successful catheterization and proper interpretation of hormone concentration differences. Textbooks of anatomy describe the veins of the pancreas in a schematical, brief, and often contradictory way. PETRéN (1929) gave a more detailed description of the veins of the head of the pancreas but his interest was focused on pyloric and duodenal drainage. With the increasing frequency of pancreatic surgery in the early fifties, studies of the anatomy of the portal venous system were carried out (DOUGLASS et coll 1950; FALCONER & GRIFFITHS 1950; DOEHNER et coll 1955). FALCONER and GRIFFITHS described the anatomy of the veins of the entire pancreas mainly from a surgical point of view.

Angiography was earlier the major method for diagnosis of pancreatic carcinoma, but in recent years it has been progressively replaced by non-invasive methods such as ultrasonography and computed tomography. However, angiography remains the only reliable method to evaluate resectability of pancreatic tumours preoperatively (SUZUKI et coll 1972; TYLéN & ARNESJÖ 1973). BURANASIRI and BAUM (1972) and others have stressed the importance of evaluating the venous involvement. Contrast enhancement of the portal system is improved in direct portography (SATO et coll 1967) as compared to the venous phase of angiography and more detailed information about the morphologic abnormalities can be obtained.

In order to establish basic knowledge for the clinical application of pancreatic phlebography the purposes of the present investigation have been:

1. To assess the venous anatomy of the pancreas and its variations and to outline the findings in normal selective phlebography (I),

2. To improve the technique of selective catheterization and account for the results of blood sampling in endocrine tumours (II),

3. To analyse the morphologic abnormalities observed at selective phlebography in patients with pancreatic and peripancreatic diseases and to discuss the clinical value of this method (III),

4. To compare the diagnostic accuracy of phlebography in pancreatic carcinoma to that of angiography with special attention to prediction of resectability (IV).

ANATOMY OF THE PANCREATIC VEINS (I).

1. Cadaver studies

In 22 human adult cadavers a barium-gelatin mass was injected into the portal venous system. After solidification of the injected material the abdominal organs were removed en bloc. Step by step dissection of the pancreas and duodenum and their draining veins was performed and documentation of the venous anatomy was made by radiographs of the specimens, drawings or photographs. The main venous drainage was found to correspond closely to the description of PETRéN (1929) and FALCONER and GRIFFITHS (1950) and their nomenclature was essentially followed.

The most constant findings were a posterior superior pancreatico-duodenal vein (21 of 22) and an anterior superior pancreatico-duodenal vein (19 of 22) draining the head of the pancreas.

The veins of the body of the pancreas varied considerably with respect to their termination. They were found to drain into all larger tributaries of the portal vein in close connection to the pancreas including gastric and large bowel veins. A previous description of the dorsal pancreatic vein as a vein draining the body (LUNDERQUIST & TYLéN 1975; REICHARDT et coll 1978) was found to be false. This vein drains a dorsomedial part of the head of the pancreas. The veins of the tail of the pancreas drained mainly to the splenic vein. Drainage to the lower polar vein of the spleen was demonstrated in one and to the transverse pancreatic vein in another specimen.

The main veins of the head of the pancreas run on the surface of the gland and only tiny veins pass through the gland. The fact that the superficial veins are dominating the phlebographic appearance limits the diagnostic value of selective pancreatic phlebography in expansive lesions within the pancreas.

2. Clinical phlebography

Provided that the catheter was correctly placed in the anterior superior or posterior superior pancreatico-duodenal vein and that an adequate amount of contrast medium was injected, demonstration of the veins of the entire head of the pancreas could be obtained by one injection.

Demonstration of veins of the body of the pancreas by injection of contrast medium into a vein of the head and vice versa occurred only occasionally.

Selective catheterization of the veins of the body of the pancreas was successful only when they drained to the inferior mesenteric or the splenic veins.

Injection into veins of the tail of the pancreas usually resulted in the filling of some minor branches and via collaterals the inflow of one or two adjacent veins was demonstrated.

PERCUTANEOUS TRANSHEPATIC PORTOGRAPHY AND SELECTIVE PANCREATIC PHLEBOGRAPHY

MATERIAL

During a six year period (December 1972 - January 1979) selective phlebography of pancreatic veins was performed on 148 patients at the Department of Diagnostic Radiology, University Hospital in Lund. Before 1974, 41 patients were examined using the transumbilical approach to the portal vein. Later all examinations were performed using a percutaneous transhepatic puncture of the portal vein.

In 61 patients (including 41 transumbilical examinations) pancreatic veins were examined en passant while the indication for portography was portal hypertension, possible metastatic lesions of the liver, or malignancy of the gastrointestinal tract.

Possible tumour in the region of the pancreas was the indication in 55 patients.

In 32 patients 45 examinations were performed for blood sampling and hormone assay.

METHODS

1. Percutaneous transhepatic portography - PTP

The technique of PTP was performed according to WIECHEL (1971) and has previously been described in detail by HOEVELS et coll (1978).

The puncture was performed with a 25-cm needle coated with a polyethylene catheter (OD 1.6 mm, ID 1.0 mm, Surgimed, Denmark). With the patient in a supine position, the puncture site was chosen in the right midaxillary line at the estimated level of the hilum of the liver. After local anaesthesia of the skin and intercostal muscles the needle was inserted in the direction of the hilum of the liver and parallel to the table. The puncture should not be deeper that the estimated position of the hilum of the liver.

After having reached this point the needle was withdrawn and a 10-ml syringe filled with saline was connected to the catheter. Alternating aspiration and flushing, the catheter was slowly withdrawn until blood was aspirated without resistance. To confirm the position of the tip of the catheter in a portal vein branch a few ml of contrast medium was injected under fluoroscopy. A 0.9-mm guide wire (Surgimed, Denmark) with a soft tip - shaped with a slight curve at the tip - was then manipulated into the main stem of the portal vein and the catheter was pushed over the guide wire into the same position.

To examine the main tributaries of the portal venous system and the parenchyma of the liver, a series of 16 films was taken (5 films/5 s, 8 films/4 s, 3 films/6 s) after injection of 40 ml of contrast medium (8 ml/s) into the superior mesenteric or splenic vein.

2. Selective pancreatic phlebography (II)

Selective catheterization of the pancreatic veins was performed using the same 0.9-mm guide wire. The guide wire was shaped according to the individual anatomic conditions and the intended course of the catheter. After manipulation of the guide wire into a pancreatic vein the catheter was pushed over the guide wire into the same position. Catheterization procedures with the catheter alone were avoided as they could result in damage to the vessel wall and subsequent extravasation of contrast medium.

For catheterization of the veins of the tail of the pancreas and sometimes - in obese patients - also for catheterization of the anterior superior pancreatico-duodenal vein, the 25-cm long catheter was changed to a 40-cm catheter of the same material and caliber.

For pancreatic phlebography 2 - 10 ml of contrast medium was injected by hand depending on the size of the vessel. Eight films were exposed (2 films/s).

3. Discussion on methodology

Three routes for catheterization of the portal venous system are practicable: the transumbilical route after surgical recannulation of the umbilical vein, the transjugular transhepatic approach, and the percutaneous transhepatic puncture of the portal vein (for references see HOEVELS et coll 1978).

The advantage of both the transumbilical and the transjugular transhepatic access is the low complication rate, as both routes avoid transperitoneal passage. However, both approaches have the disadvantage of making selective catheterization of the veins of the entire pancreas difficult.

Using the percutaneous transhepatic approach to the portal vein selective catheterization of the veins of the entire pancreas is possible as the course of the catheter is relatively straight.

A complication rate of 3 per cent in 200 transhepatic examinations of the portal vein (HOEVELS et coll 1978) is found acceptable.

When catheterization of the entire pancreatic venous system for phlebography and blood sampling was desired, one projection was sufficient for documentation and interpretation. With detailed knowledge of the pancreatic venous ana-

tomy, the AP-projection allows identification of the anterior and posterior pancreatico-duodenal veins and their ramifications.

In patients with possible carcinoma of the pancreas the interest as a rule was limited to one part of the pancreas, usually the head of the pancreas. In these cases the morphology of the veins had to be evaluated and therefore often two projections of the same injected vessel were necessary. Beside the AP-projection, we used the left anterior oblique and lateral projections and found the latter more instructive. However, it was difficult to obtain satisfactory film quality in obese patients.

As a routine a series of 8 films (2 films/s) was exposed during selective phlebography. This series is short and does not allow exposure before injection of contrast medium to obtain a plain film for subtraction. If subtraction is planned a series of 6 - 8 films (1 film/s) should be exposed. It will include at least one or two films with an optimal venous opacification.

RESULTS AND DISCUSSION

Blood sampling in endocrine tumours (II)

In 32 patients selective catheterization of the pancreatic veins for blood sampling and hormone assay was performed. All patients were also examined by angiography. The results of preoperative localization of endocrine tumours by both methods were compared.

In 16 patients without verified tumours, both angiography and the hormone analyses were negative concerning demonstration of an endocrine tumour. One patient examined for a possible Zollinger-Ellison syndrome had multiple submucosal duodenal lipomas and both arteries and veins were stretched and displaced.

In seven patients with hyperinsulinism the final diagnoses were B-cell adenom in five and B-cell hyperplasia in two patients. Two adenomas were correctly lo calized by both methods. Angiography failed to localize the source of increase insulin production in five of seven patients, two of which had B-cell hyperpla- sia.

Blood sampling and insulin determination correctly localized four of five adeno mas and B-cell hyperplasia in two patients.

In one patient with an insulinoma the tumour could not be localized by arterio- venous hormone differences. In this case phlebography revealed an anomalous venous drainage from the head of the pancreas directly to the left lobe of the liver. The adenoma was found in this part of the head of the pancreas.

Three patients with glucagonoma syndrome were examined. Two tumours were correctly localized by angiography, the third was found retrospectively.

All glucagon-producing tumours were correctly localized by hormone analyses. Besides glucagon one tumour contained insulin and serotonin and this patient also had increased insulin concentrations in a vein draining the distal part of the tail of the pancreas.

Four patients with Zollinger-Ellison syndrome were examined. Three patients had multiple gastrinomas. In none of these patients were all the tumours de- monstrated by angiography. Hormone analyses also failed to localize the tu- mours but generally elevated gastrin concentrations in the portal venous sys- tem were suggestive of multiple tumours. In one patient angiography demonst- rated a 1.5-cm tumour in the body of the pancreas and hormone analyses loca- lized gastrin releasing tissue in the head. This patient refused surgery and tumour localization was not verified.

Two more islet cell tumours were observed at angiography. Operation disclosed one to be a somatostatinoma. In this patient blood samples were postoperatively once again analysed and veins draining the tumour contained increased somatostatin concentrations. The tumour in the other patient could not be classified by samples or immunocytochemistry, but was classified as D_1-cell tumour by electronmicroscopy.

Postoperative catheterization for blood sampling was performed in nine patients. In one with Zollinger-Ellison syndrome there was evidence of recurrence which was verified operatively.

The angiographic accuracy in localization of insulinomas varies widely. However, according to the literature, the majority of tumours can be localized (BOOKSTEIN & OBERMAN 1966; BOIJSEN & SAMUELSSON 1970; SKJOLDBORG & MADSEN 1971; FUDJI et coll 1974; STEFANINI et coll 1974; FULTON et coll 1975) although the pitfalls of angiography in this field are well known (KOROBKIN et coll 1971). The combination of angiography and selective catheterization of the pancreatic veins for hormone assay provides the most accurate preoperative localization and should consequently be performed if possible.

The sampling procedure should include selective catheterization of the pancreatic veins and not be limited to the main portal vein tributaries (II, Table 1).

Phlebography should always be performed for documentation of the individual anatomy, the location of blood sampling, and possible variations of the venous drainage. The phlebographic anatomy can be identified by peroperative dissection of the veins and can lead the surgeon to the tumour if it is not palpable.

Venous morphology in pancreatic and peripancreatic diseases (III)

Selective phlebograms in 67 patients with proven disease in the pancreaticoduodenal region were evaluated. The final diagnoses were: pancreatic carcinoma (35), islet cell tumour or islet cell hyperplasia (16), chronic pancreatitis (5), carcinoma of the extrahepatic bile ducts (9), submucosal duodenal lipoma (1), and retropancreatic malignant lymphoma (1).

In 21 of 35 patients with pancreatic carcinoma occlusion of veins of the head of the pancreas could be demonstrated at the site of the tumour and this finding was regarded as diagnostic for carcinoma. In another four patients none of the veins of the head of the pancreas could be catheterized, probably due to occlusion of these veins. The tumours were 6 to 10 cm in diameter in these cases. The minimum size of demonstrable tumours was 3 cm.

In patients with chronic pancreatitis the veins were slender, irregular, and abruptly changed their course but they were generally patent. When occlusion of veins did occur the discrepant finding of patent smaller veins adjacent to the occlusion allowed the differentiation between chronic pancreatitis and a carcinoma larger than 3 cm in size.

However, the diagnosis of a pancreatic carcinoma today can be obtained by ultrasonography, computed tomography, ERCP or PTC in combination with fine needle aspiration biopsy in the majority of cases. Phlebography should therefore be performed only in rare special cases.

In 11 of 16 patients with islet cell tumours or islet cell hyperplasias no morphologic abnormalities were found. In patients with lesions larger than 4 cm in diameter displacement of the veins was demonstrated. The value of phlebography in endocrine tumours is almost exclusively to document the venous anatomy in order to allow a correct interpretation of blood sample analyses.

In nine patients with carcinoma of the extrahepatic bile ducts (proximal to the pancreas) the pancreatic veins were normal except in one patient in whom dilated veins were found near the hepato-duodenal ligament. The choledochal veins were widened and tortuous in one patient and occluded in another.

Two extrapancreatic lesions (submucosal duodenal lipomas and retropancreatic malignant lymphoma) caused stretching and displacement of pancreatic veins without other morphologic changes.

Carcinoma of the pancreas - evaluation of resectability (IV)

In 33 of 35 patients with pancreatic carcinoma both angiography of the superior mesenteric and coeliac arteries and portography including selective pancreatic phlebography were performed.

In 28 of 33 patients the tumour diagnosis was made by angiography. Arterial encasement limited to small intrapancreatic arteries was evident in 12 patients and in 11 there was also involvement of the gastroduodenal artery. Encasement of other extrapancreatic arteries was found in five patients. Evaluation of the venous phase of the angiographic studies disclosed venous lesions in seven patients while in three there was suspicion of venous involvement.

In 21 of 33 patients the tumour diagnosis could be made by selective pancreatic phlebography and in four the veins of the head of the pancreas were found to be obliterated, suggesting tumour growth. Infiltration of the superior mesenteric vein, portal vein, or confluence was found in four patients. A marked stenosis of these veins indicated tumour growth adjacent to the vessel in 12 patients. A smooth local impression of the vein was found in seven cases and in two the venous involvement was doubtful. Eight portograms revealed no signs of involvement of the portal, the superior mesenteric, or the splenic vein.

In all cases PTP showed morphologic changes of the portal system more distinctly than did the venous phase of superior mesenteric angiograms. In 12 cases portography disclosed involvement of the portal system undetected at angiography. In five cases the involvement of the veins demonstrated at portography was the only sign of non-extirpability.

A clear correlation has been demonstrated between angiographic findings, operability, and survival time (SUZUKI et coll 1972; TYLéN & ARNESJÖ 1973). In the present series surgery was not radical in any patient with clearcut involvement of the veins. In all cases with minor displacement in which resection was performed the operations were technically difficult and complicated by intraoperative bleeding.

The results indicate that patients with stenosis of the main stems of the portal venous system are not suitable candidates for radical surgery.

Portography provided useful information for evaluation of resectability of pancreatic carcinoma and should be used complementary in patients in whom angiography does not give unequivocal information about non-resectability. Selective phlebography, however, is not relevant for this purpose.

GENERAL SUMMARY AND CONCLUSIONS

1. The normal anatomy of the pancreatic veins has been reevaluated. The veins of the body of the pancreas were found to vary considerably and can terminate in any large portal vein tributary adjacent to the body of the pancreas.

2. The normal appearance of selective phlebograms of the head, the body and the tail of the pancreas is described.

3. The technique of selective catheterization of pancreatic veins using the percutaneous transhepatic puncture of the portal vein was proved to be the most convenient for catheterization of the veins of the entire pancreas and is described in detail.

4. The results of blood sampling in endocrine tumours of the pancreas indicate that selective catheterization of pancreatic veins is necessary and that the anatomy has to be documented by phlebography.

5. Evaluation of venous morphology is without value in patients with islet cell tumours.

6. The diagnosis of a pancreatic carcinoma larger than 3 cm in size can be made by phlebography.

7. Differentiation between carcinoma and chronic pancreatitis may be possible, although of minor clinical value.

8. Differentiation between pancreatic and peripancreatic disease is possible, but of no clinical importance.

9. Portography is a useful complement to angiography in evaluation of resectability of pancreatic carcinoma. It should be performed in all cases in which angiography does not give unequivocal information about non-resectability.

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ACKNOWLEDGEMENT

I want to express my thanks and gratitude to:

Docent Anders Lunderquist for all his advice, guidance and encouragement throughout this work,
Professor Erik Boijsen and Docent Torben Owman for valuable advice and stimulating critics,
Docent Stig Ingemansson, Docent Ingemar Ihse and Doctor Robert Cameron for support and collaboration,
Docent Ulf Tylén for the igniting spark,
Miss Eva Jönsson, Miss Karin Jönsson and Mrs Britt Nihlén for secreterial help.

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ANATOMY OF THE PANCREATIC VEINS

A post mortem and clinical phlebographic investigation

W. REICHARDT and R. CAMERON

Selective catheterization of the pancreatic veins for clinical application can be performed using the percutaneous transhepatic or the transumbilical approach to the portal vein (GÖTHLIN et coll. 1974).

Pancreatic phlebography is important in connection with blood sampling for hormone assay in endocrine tumours of the pancreas (INGEMANSSON 1977, LUNDERQUIST et coll. 1978) and is also of use in the morphologic examination of inflammatory pancreatic disease and exocrine tumours (REICHARDT et coll. 1978). The description of the venous anatomy of the pancreas in textbooks is schematical and brief and often contradictory. PETRÉN (1929) gave a more detailed description of the pancreatico-duodenal venous anatomy but mainly the pyloric and duodenal drainage. With the increasing frequency of pancreatic surgery in the early fifties, reports on the anatomy of the blood vessels of this region appeared (DOUGLASS et coll. 1950, FALCONER & GRIFFITHS 1950, DOEHNER et coll. 1955). FALCONER & GRIFFITHS described the anatomy of the entire pancreas in 50 specimens, mainly from a surgical point of view.

The aim of the present report is to describe the venous anatomy of the pancreas and its variations to provide a guide for selective catheterization for blood sampling and to outline the normal selective phlebography of pancreatic veins.

Post mortem phlebography

Material and Methods

The material comprised 22 human adult cadavers without signs or history of pancreatic disease.

Injection technique. At autopsy a polyethylene catheter with a diameter of 3 to 4 mm was inserted in a peripheral tributary of the superior mesenteric vein. Preferably the ileocolic vein was used as this vessel is easily dissected without injury of other portal vein tributaries. The tip of the catheter was advanced to the estimated position of the confluence of the superior mesenteric and splenic veins and the catheter was tied with a ligature. Injury of other portal vein tributaries was carefully avoided.

A modified Schlesinger buffered iodinated gelatin injection agent (HALES & CARRINGTON 1971) was prepared. Barium sulphate was used as pigment and the solidification time was adjusted to about 30 min. As rapidly as possible 150 to 200 ml of the agent was injected by hand, since the consistency increased after only a few minutes. Filling of smaller gastric veins and superficial veins of the liver and spleen indicated as a rule also filling of the pancreatic veins. The agent was allowed to solidify for 45 min. The abdominal and retroperitoneal organs were then removed en bloc. The portal vein was cut off at the hilum of the liver. The main tributaries of the portal vein were identified and subsequently, step by step, the pancreas and its draining veins were dissected.

In some early cases the abdominal and retroperitoneal organs were removed en bloc, before the catheter was inserted into the portal vein in the hilum of the liver or into the splenic vein in the hilum of the spleen. The periphery of the superior and inferior mesenteric veins was ligated. In these instances it was difficult to avoid leakage of contrast agent. Injection of the contrast agent before removal of the organs was later found to be preferable.

Radiographic technique. In some instances survey films were exposed immediately after injection

Submitted for publication 2 July 1979.

Fig. 1. Radiography of pancreaticoduodenal specimens. PV = portal vein, SPV = splenic vein, SMV = superior mesenteric vein, IMV = inferior mesenteric vein, ASPD = anterior superior pancreaticoduodenal vein, PSPD = posterior superior pancreaticoduodenal vein, PIPD = posterior inferior pancreaticoduodenal vein, AIPD = anterior inferior pancreaticoduodenal vein, CV = coronary vein. a) In this specimen veins of the body of the pancreas drain to the coronary vein. Veins of the tail of the pancreas drain to the splenic vein. b) In this specimen a vein (→) drains a ventrocranial part of the head of the pancreas and the cranial part of the duodenum to the portal vein. Inflow of the vein not filled with contrast medium. The dotted lines demonstrate its course as found by dissection. Ampullary shape of the periphery of duodenal veins (↔).

a b

Fig. 2. a) Dorsal aspect of dissected specimen. Small posterior superior pancreaticoduodenal vein (↠), dominating dorsal pancreatic vein (↠). An arcade runs in the pancreaticoduodenal sulcus caudally ending in the first jejunal vein (→). b) Ventral aspect at the hepatoduodenal ligament. CHV = choledochal veins. PV = portal vein, GB = gallbladder, P = head of pancreas.

of the contrast agent. However, as the radiography equipment of the autopsy room did not allow adequate examination quality, films were later on exposed only after isolation of the pancreatic tissue. with the specimen in contact with fine-grain films.

In two instances only survey films with the pancreas in situ were obtained. As the specimens were dissected before complete solidification of the injection agent, filling of the pancreatic veins was incomplete in some cases after dissection. However, in these cases, the veins could be identified by dissection, and documentation of the anatomy was made by drawings or photographs.

Results

Veins of the head of the pancreas. The anterior aspect of the head of the pancreas was drained mainly by the anterior superior pancreaticoduodenal vein in 19 cases (Fig. 1). This vein joined the gastrocolic trunk, which ended in the right lateral wall of the superior mesenteric vein within 1 to 3.5 cm (average 2 cm) off the confluence of the splenic and superior mesenteric vein (in the following text named confluence).

In one case only tiny veins ran to the gastrocolic trunk and the main ventral drainage was by the anterior inferior pancreaticoduodenal vein to the superior mesenteric vein. An ant. inf. vein was identified in 12 cases. The vein ended in the first jejunal vein in 7 instances, in the superior mesenteric vein in 4, and was a tributary to the anterior superior vein in one case.

The dorsal aspect of the head was usually drained by the posterior superior pancreaticoduodenal vein running directly to the portal vein within 1.5 to 3 cm (average 1.8 cm) off the confluence. The post. sup. vein was identified in 21 cases. These veins draining the dorsal part of the head opened into the dorsal circumference of the portal vein. In 2 instances a ventral vein (Fig. 1 b) drained the cranioventral part of the head and ended in the ventral circumference of the portal vein 3.2 and 3.5 cm, respectively, from the confluence. These veins drained even the cranial part of the duodenum and probably the pyloric region (the pylorus was already cut off before radiography). In 8 instances a dorsal pancreatic vein was observed draining the mediodorsal part of the head and ending in the dorsal wall of the confluence. In 3 cases the dorsal pancreatic vein was the dominant vein of the dorsal aspect of the head (Fig. 2 a).

In 2 instances the dorsal pancreatic vein formed an arcade together with the post. inf. pancreaticoduodenal vein, running in the pancreaticoduodenal sulcus without changing its caliber (Fig. 2 a). In most cases only smaller collaterals between the post. sup. and the post. inf. pancreaticoduodenal veins were observed. The post. inf. pancreaticoduodenal vein could be identified in 9 cases. Insertion into the first jejunal vein was observed in 6 instances, into the superior mesenteric vein in one

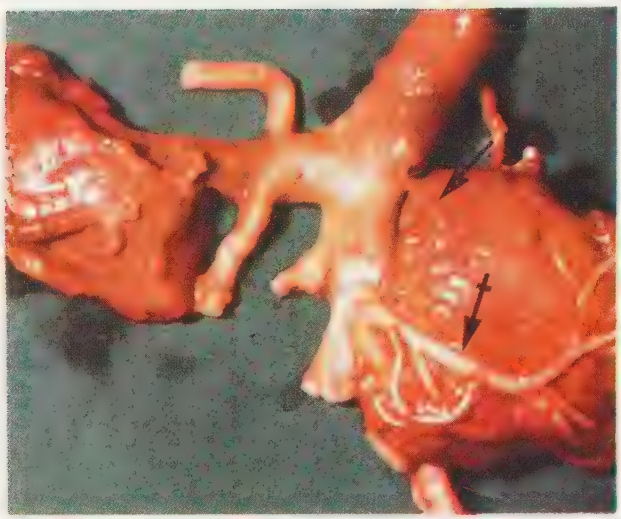


Fig. 3. Dorsal aspect of dissected specimen, body of the pancreas removed. Small post. sup. pancreaticoduodenal vein (→), dominating post. inf. pancreaticoduodenal vein (↠) draining to the first jejunal vein.

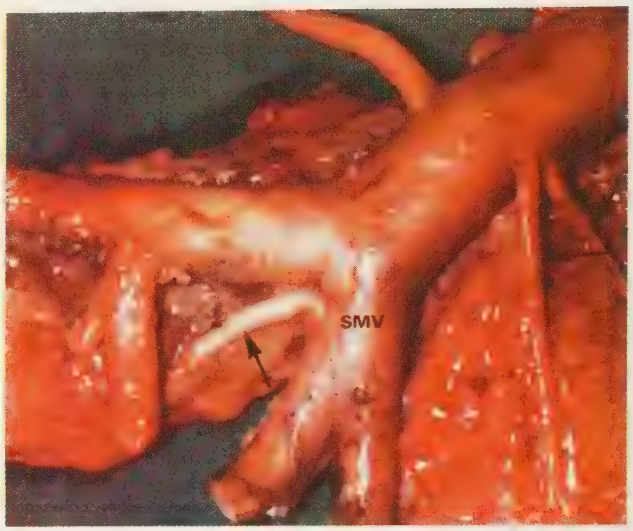


Fig. 4. Dorsal aspect of dissected specimen. Duplicated post. sup. pancreaticoduodenal vein (→). Transverse pancreatic vein (↠) draining to the sup. mesenteric vein (SMV) near the confluence.

case, into the second jejunal vein in one, and the post. inf. pancreaticoduodenal vein was a tributary to the dorsal pancreatic in one. The post. inf. pancreaticoduodenal vein was the dominant vein of the dorsal aspect of the head in one case (Fig. 3).

Veins of the body of the pancreas. The tiny veins of the pancreatic body were collected in main branches with considerably varying termination. The transverse pancreatic vein running along the inferior border of the body of the pancreas could be identified in 16 specimens. Its termination was the inferior mesenteric vein in 5 cases, the superior mesenteric vein in 3 (Fig. 4), the confluence in 3, and the splenic vein in 5.

Veins of the body running to the post. sup. pancreaticoduodenal vein were found in 3 instances, to the ant. sup. vein in one.

Collaterals to the coronary vein were demonstrated in 8 specimens (Figs 1 a, 5).

In 2 cases where the pancreatic body was located cranio-ventrally to the confluence, several smaller veins drained into the cranial wall of the region of the confluence.

Veins of the tail of the pancreas drained as a rule directly to the splenic vein, entering into its ventrocaudal circumference. As the tail of the pancreas was usually in close connection with the ventrocaudal wall of the splenic vein, these tail veins were very short and embedded in pancreatic tissue.

The number of tail veins draining to the splenic vein which could be identified varied from 3 to 9 (average 6). In cases with a large transverse pancreatic vein, which also collected veins of the tail, the number of veins draining to the splenic vein were less. In one specimen the transverse pancreatic vein was also the main vein of the tail, collecting 5 tributaries. Two tail veins draining to the lower polar vein of the spleen were demonstrated in 2 cases (Fig. 1 b).

The inferior mesenteric vein was identified in all

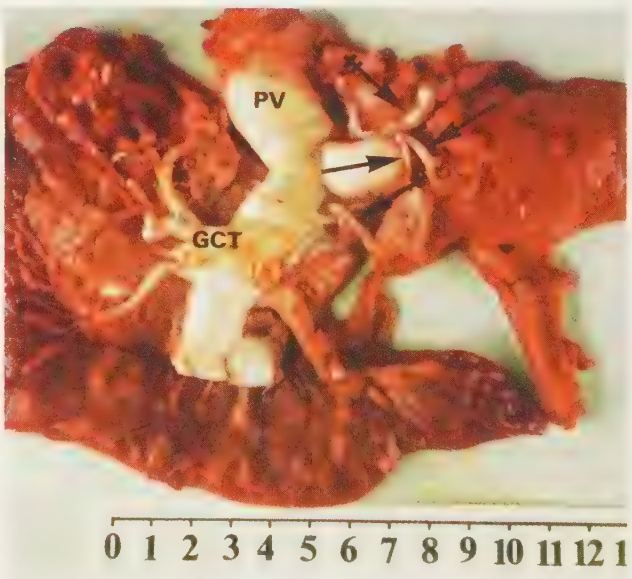


Fig. 5. Anterior aspect of dissected specimen. Pancreatic tissue anterior to the confluence is removed. PV = portal vein, GCT = gastrocolic trunk. Coronary vein (↠), transverse pancreatic vein (↠). Veins of the body draining to the coronary vein (→).

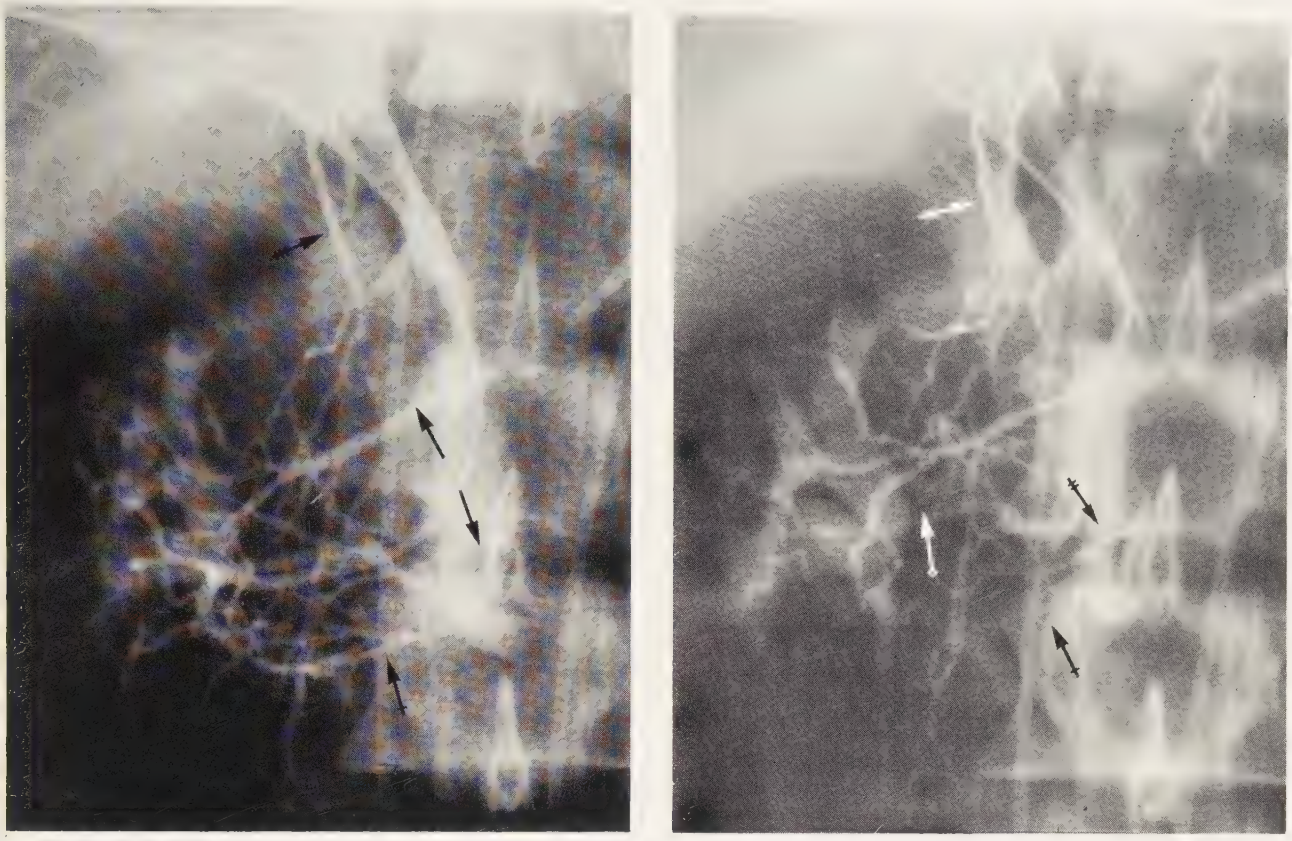


Fig. 6. Normal phlebography of the head of the pancreas. a) Injection into the ant. sup. pancreaticoduodenal vein. Via collaterals filling of the dorsal pancreatic vein (→), the dominant vein of the dorsal aspect, the ant. inf. (↔) and the post. inf. pancreaticoduodenal vein (⇹). Filling of veins in the hepatoduodenal ligament (⇹). b) Injection into dorsal pancreatic vein, almost identical appearance. Ant. sup. (⟲), ant. inf. (↔) and post. inf. (⇹) pancreaticoduodenal veins, and veins in the hepatoduodenal ligament (⇹).

but one case. It terminated in the splenic vein at the most 3.6 cm (average 1.8 cm) from the confluence in 15 cases. In one specimen the confluence was the point of inflow and in 5 it ended in the superior mesenteric vein at the most 1.5 cm (average 0.9 cm) from the confluence.

The coronary vein could be demonstrated in 21 of 22 specimens. In 9 cases this vein drained to the cranial circumference of the confluence, in 6 cases to the splenic vein within a distance of 2.5 cm (average 1.1 cm) from the confluence and in 4 cases to the portal vein within 2.5 cm (average 1.7 cm) from the confluence. In 2 specimens the coronary vein drained directly to intrahepatic portal vein branches of the left lobe.

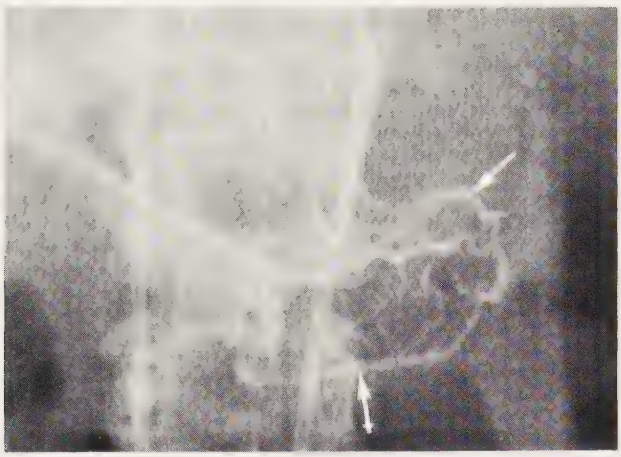
Further observations. All main veins of the head and body of the pancreas were observed on the surface of the organ or only partly covered by a very thin layer of pancreatic tissue. The veins embedded in the tissue and connecting superficial, dorsal, and ventral veins were tiny. Only the veins of the tail had no, or only a short, extrapancreatic course.

No special interest was paid to the veins of the common bile duct, which were often visible at clinical phlebography of the veins of the pancreatic head. However, in one instance the choledochal veins were dissected. Several collaterals existed to ventral veins of the head and to an arcade running along the dorsal pancreaticoduodenal border. The veins and their tributaries could be traced to the hilum of the liver (Fig. 2 b). Collaterals or inflow to intrahepatic portal veins were not observed.

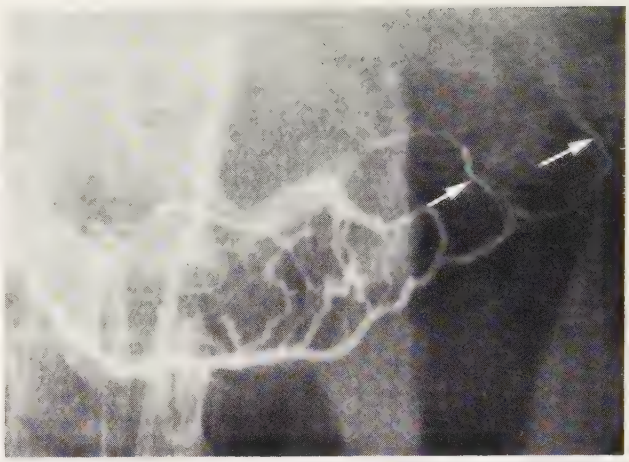
Clinical phlebography

Material and Methods

During 1972 to 1978 selective pancreatic phlebography was performed in 140 patients at this Depart-



a



b

Fig. 7. Phlebography of the body of the pancreas. a) Injection into a vein draining to the splenic vein. Filling of another vein ending in splenic vein (→) and filling of transverse pancreatic vein (↔). b) Injection into transverse pancreatic vein. Filling of the same veins as in (a) and of two veins of the tail (→).

ment of Diagnostic Radiology. During 1972 to 1974, 41 patients were examined using the transumbilical approach to the portal vein. Later only percutaneous transhepatic puncture of the portal vein was used.

In 61 patients the indication for portography was portal hypertension, suggestion of metastatic lesions of the liver, or malignancy of the gastrointestinal tract, and pancreatic phlebography was performed en passant.

In 32 patients the examination was performed for blood sampling and hormone assay. In these cases as many veins as possible were catheterized. The success rate increased during the period. In general at least 4 veins of the pancreas were catheterized in this group.

A possible tumour in the region of the pancreas was the indication in 55 patients and selective catheterization was limited to the area of interest, usually the head of the pancreas.

The technique of percutaneous transhepatic portography is described in detail elsewhere (GÖTHLIN et coll. 1974, HOEVELS et coll. 1978, REICHARDT & INGEMANSSON 1980), therefore only a short description is given here. The puncture was performed with a 25 cm needle coated with a polyethylene catheter (OD 1.6 mm, ID 1.0 mm, Surgimed, Denmark). With the catheter in the portal vein a 0.9 mm guide wire was introduced for further catheterization of the pancreatic veins. The tip of the guide wire was shaped according to the anatomy and introduced into a pancreatic vein. The catheter was then pushed over the guide wire into the vein.

Phlebography was carried out by manual injection of 2 to 10 ml of Isopaque Coronar, 370 mg I/ml (Nyegaard, Norway). The volume was adjusted to the size and flow of the injected veins. Eight films were exposed at a rate of 2/s.

The catheter should not be allowed to advance into sub-branches in order to obtain a proper filling of the pancreatic and duodenal veins. Injection into peripheral tributaries results in incomplete filling and the appearance of the films may mimic and expanding lesion. Injection of too large volumes of contrast medium resulted in extravasation in 11 cases.

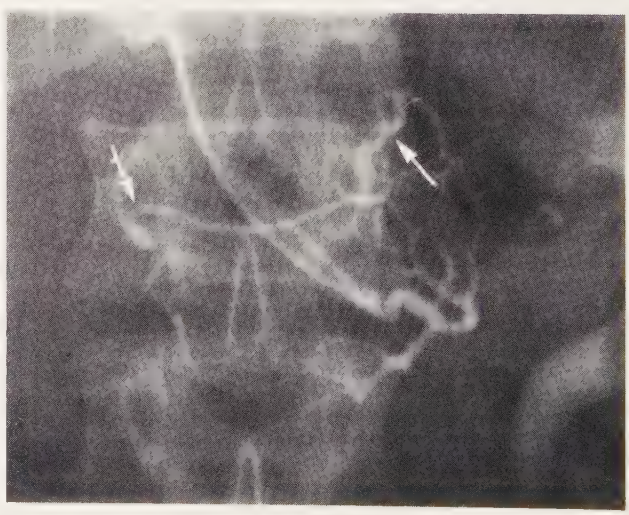
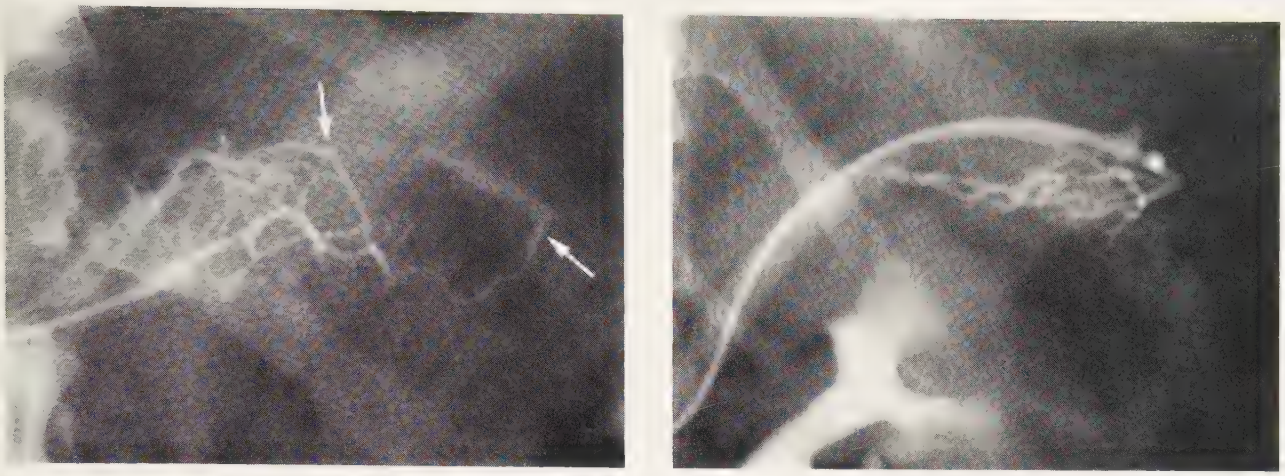


Fig. 8. Injection into a vein draining to the splenic vein. Collaterals to coronary vein (→) and to post. sup. pancreaticoduodenal vein (↔).



a b

Fig. 9. Normal phlebography of the tail. a) Injection into a vein of the body. Filling of veins of the tail. Various points of inflow of veins of the tail into the splenic vein (→). b) Injection of a vein of the tail near the hilum of the spleen.

Phlebographic findings

Selective injection of contrast medium into the post. sup. pancreaticoduodenal vein usually caused filling of the majority of the duodenal branches. The ant. sup. vein was also filled via collaterals in the parenchyma of the pancreas, and vice versa (Fig. 6). If several veins draining to the portal vein or confluence were present, these were also filled by injection into one of them. Collaterals to the body of the pancreas were infrequently demonstrated. In these instances usually a branch to the main stem of the post. sup. vein was present. Flow of contrast medium from the post. sup. or ant. sup. vein to the transverse pancreatic vein was not observed. Demonstration of the ant. inf. or post. inf. vein by injections into the ant. sup. or post. sup. vein was a frequent but inconstant finding, probably depending mainly on the size of the inferior veins. Veins in the hepatoduodenal ligament with approximately the same diameter as the main veins of the head were not constantly filled. In one case an ant. inf. vein draining to the superior mesenteric vein was catheterized selectively.

The right coronary vein was filled by injection into the post. sup. vein in 4 cases. In these instances the right coronary vein had a smaller diameter than the post. sup. one, increasing in size in its course along the minor curvature of the stomach.

The shape of the peripheral branches of the duodenal and proximal jejunal veins was usually ampullary.

Veins of the body of the pancreas. Selective examination of the veins of the body was often difficult to perform as the majority of these veins were tributaries to veins draining other organs (coronary vein, inferior mesenteric vein) or to veins of the head of the pancreas. The transverse pancreatic vein was easy to catheterize when draining directly to the splenic vein, to the superior mesenteric vein, or to the inferior mesenteric vein near its inflow to the superior mesenteric vein or confluence (Fig. 7).

Injection into the transverse pancreatic vein usually resulted in filling of the veins of the body positioned to the left of the superior mesenteric vein, demonstrating the inflow into the splenic vein and—if present—into the coronary vein (Fig. 8). Collaterals to the post. sup. pancreaticoduodenal vein were filled in a few cases.

Selective phlebography of veins draining to the coronary vein was not performed and appears to be difficult due to their position and direction of inflow.

Veins of the tail of the pancreas. Injection into a vein of the tail usually resulted in the filling of some minor branches and via collaterals the inflow of one or two adjacent veins was demonstrated (Fig. 9). Collaterals to the transverse pancreatic vein were observed.

The great number of separate veins of the tail draining into the splenic vein was the reason why a complete demonstration of all these veins became a difficult and time-consuming procedure; in only a few of the present patients appeared the veins of the body and the tail to be demonstrated completely.

Discussion

The literature on venous anatomy of the pancreas is limited. A detailed description of the venous anatomy of the pancreatic head was given by PETRÉN and of the entire pancreas by FALCONER & GRIFFITHS. In the present specimens the main venous drainage of the head of the pancreas was found to correspond closely to these descriptions and their nomenclature was followed essentially. The drainage of the posterior aspect of the head by one or several posterior superior veins and drainage of the anterior aspect by the anterior superior vein was an almost constant finding. In only one case was the main drainage of the anterior aspect by the ant. inf. vein and, also in one case only, was the post. inf. the dominating draining vein of the dorsal aspect. PETRÉN described one case with two post. sup. veins ending in intrahepatic portal veins. Also in the present series the post. sup. vein could be duplicated and even 3 pancreatic veins terminating in the portal vein were observed. Usually the post. sup. vein ended in the dorsocaudal circumference of the portal vein. Veins inserting ventrally were observed twice but these veins drained a minor ventral aspect of the head and may represent collaterals to pyloric veins. Veins draining to the confluence were called dorsal pancreatic veins in analogy to the arterial nomenclature. Because of lack of experience previously an erroneous conclusion had been arrived at, namely that this vein drained the body into the anterior aspect of the confluence (LUNDERQUIST & TYLÉN 1975, REICHARDT et coll.). In all the present specimens, where a vein draining into the confluence was found, it ended dorsally. Furthermore, all these veins drained the dorsal aspect of the head and should be regarded as a duplication or variation of the post. sup. pancreaticoduodenal vein. This corresponds to the findings of FALCONER & GRIFFITHS who emphasized the fact that, despite the close relationship of the neck of the pancreas to the portal vein, in no case did a pancreatic tributary enter the portal vein on its anterior aspect. This was also true in the present series regarding the region of the confluence.

In analogy to the arterial nomenclature, the vein inferior to the pancreatic body (inferior pancreatic vein, FALCONER & GRIFFITHS) was here called transverse pancreatic vein.

Veins of the body of the pancreas may drain to any main tributary of the portal vein terminating in that region. This fact must be considered when catheterization is performed for blood sampling in endocrine tumours. Veins draining to the coronary vein were relatively common in the present series.

The fact that the main veins of the head of the pancreas run on its surface limits the diagnostic value of selective pancreatic phlebography in expanding lesions of the pancreas.

The size of exocrine tumours demonstrated at pancreatic phlebography were more than 3 cm in diameter (REICHARDT et coll.). This relatively large size may be surprising, but it may be difficult to observe occluded veins inside the gland because of superimposition by normal vessels on the surface of the organ.

SUMMARY

The venous anatomy of 22 autopsy specimens of human pancreas was examined by dissection and radiography after injection of gelatin agent. The most constant findings were the posterior superior pancreaticoduodenal vein draining to the portal vein and the anterior superior pancreaticoduodenal vein draining to the gastrocolic trunk and superior mesenteric vein. Both veins were identified in 21 and 20 of 22 cases, respectively. All other pancreatic veins varied considerably in their course. The normal findings in clinical selective pancreatic phlebography based on 148 examinations are described.

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SELECTIVE VEIN CATHETERIZATION FOR HORMONE ASSAY IN ENDOCRINE TUMOURS OF THE PANCREAS

Technique and results

W. REICHARDT and S. INGEMANSSON

The morphology of the pancreas can be examined using different techniques, such as scintigraphy, ultrasound, computer tomography, angiography and phlebography. Active endocrine tumours are often too small to be detected with most of these methods. Successful localization of insulinomas by computer tomography has been reported in a few cases (FRICKE et coll. 1978). Best results of the imaging techniques are obtained with angiography. The reported accuracy varies widely between 20 and 100 per cent (BOOKSTEIN & OBERMAN 1966, BOIJSEN & SAMUELSSON 1970, SKJOLDBORG & MADSEN 1971, FUJII et coll. 1974). The majority of authors account for about 80 per cent positive angiographic diagnoses in patients with proved insulinomas. However, GRAY et coll. (1970) pointed out that the angiographic accuracy in series comparing positive and negative findings was 63 per cent.

Selective vein catheterization with hormone assay is since long used for diagnosis and localization of parathyroid and adrenal tumours. The percutaneous transhepatic approach to the portal vein (WIECHEL 1971) made an extensive selective catheterization of the pancreatic veins feasible (LUNDERQUIST & TYLÉN 1975). It has been demonstrated that localization of insulin-, glucagon-, gastrin-, and serotonin-producing tumours of the pancreas by arteriovenous hormone gradients is possible (INGEMANSSON 1977). The method has proven to be sensible enough to locate microscopic lesions as islet cell hyperplasia (INGEMANSSON et coll. 1977). The present report summarizes the pertinent anatomy of the pancreatic veins, describes the technique of selective catheterization and accounts for the results.

As the venous anatomy of the pancreas has been described in detail previously (REICHARDT & CAMERON 1980), only a short summary is given here (Fig. 1).

The venous drainage of the pancreas is varying. Most constant is the venous anatomy of the head of the pancreas. The anterior superior pancreatico duodenal vein is draining the ventral part of the head joining the gastrocolic trunk, which is ending in the superior mesenteric vein. The dorsum of the head is drained by the posterior superior pancreaticoduodenal vein which empties into the dorsolateral aspect of the portal vein. The post. sup. vein may be double or even triple. In these instances one of these veins may drain a ventrocranial part of the head of the pancreas. The veins of the uncinate process are ventrally connected in an anterior inferior pancreaticoduodenal vein and dorsally in a posterior inferior pancreaticoduodenal vein. Both end into the superior mesenteric or the first jejunal vein. Often a ventral and a dorsal arcade are running in the pancreaticoduodenal sulcus along the duodenal loop connecting the main veins of the head.

The body of the pancreas is often drained by a transverse pancreatic vein ending in the inferior mesenteric, superior mesenteric, or splenic vein. Furthermore small branches can join the coronary vein or end in the post. sup. vein. Veins of the body

Submitted for publication 11 July 1979.

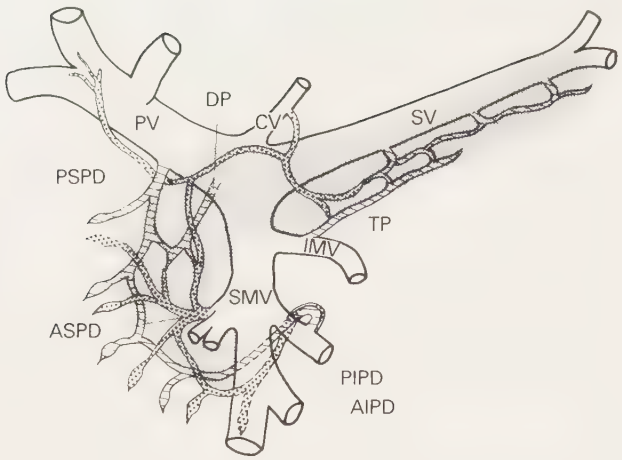


Fig. 1. Venous anatomy of the pancreas, schematic. PV = portal vein, SV = splenic vein, SMV = superior mesenteric vein, IMV = inferior mesenteric vein, PSPD = posterior superior pancreaticoduodenal vein, ASPD = anterior superior pancreaticoduodenal vein, PIPD = posterior inferior pancreaticoduodenal vein, AIPD = anterior inferior pancreaticoduodenal vein, TP = transverse pancreatic vein, DP = dorsal pancreatic vein, CV = coronary vein. The dotted veins are anterior, the striped veins posterior to the pancreas.

may even drain directly into the splenic vein as the veins of the tail of the pancreas. Sometimes a vein of the distal part of the tail ends in a lower polar vein of the spleen.

Material

From January 1974 until November 1978, 45 triple catheterizations of the pancreatic veins were performed in 32 patients, 17 females and 15 males, aged 23 to 70 years. Fourteen patients were examined in order to locate clinically and laboratory confirmed endocrine tumours of the pancreas (7 patients with hyperinsulinism, 4 patients with Zollinger–Ellison syndrome, 3 patients with glucagonoma syndrome). Thirteen examinations were performed postoperatively to confirm surgical radicality or to locate recurrences. In 18 patients catheterization was employed to diagnose and locate or to exclude endocrine tumours, when clinical symptoms suggested this diagnosis but laboratory findings were nonconclusive.

Methods

Catheterization technique

Percutaneous transhepatic puncture of the portal vein was performed according to the technique introduced by WIECHEL and described in detail previously (GÖTHLIN et coll. 1974, HOEVELS et coll. 1978). Using a 25 cm long needle (Surgimed, Denmark) coated with a polyethylene catheter (OD 1.6 mm, ID 1.0 mm) the puncture was performed in the right midaxillary line towards the hilum of the liver. The needle was withdrawn and the catheter slowly pulled back until blood could be aspirated without resistance. After injection of a small amount of contrast medium during fluoroscopy to assure the correct position in a portal vein branch, a guide wire with soft tip was manipulated into the portal vein. The catheter was then pushed over the guide wire into the same position.

A cranially directed puncture was avoided as a sharp intrahepatic angle of the catheter would be the result and the further catheterization procedures would be difficult. A puncture directed in a right angle to the spine or slightly caudally was preferred. The latter was often practicable in elderly patients without risk to hurt the lung.

All catheterizations were performed using a 0.9 mm guide wire (Surgimed, Denmark) with a soft tip but stiff enough to be formed by hand according to the desired course of the catheter. This guide wire was also stiff enough to allow the catheter to be pushed over it without leaving its position in a portal vein tributary. Catheterization procedures with the catheter alone were strictly avoided as they could result in injury to the vessel wall and subsequent extravasation of contrast medium. For the same reason the catheter should not be allowed to advance beyond the tip of the guide wire.

A series of 16 films was exposed (5 films/5 s, 8 films/4 s, 3 films/6 s) after injection of 40 ml of Isopaque Coronar, 370 mg I/ml (Nyegaard, Norway), at a rate of 8 ml/s, into the superior mesenteric vein or splenic vein to document the position of the main tributaries of the portal vein and to examine the parenchyma of the liver.

Selective catheterization of the pancreatic veins was started with a main vein of the head, the posterior or the anterior superior pancreaticoduodenal vein.

A 2 cm long curve of the tip of the guide wire (Fig. 2 a) was as a rule usable to enter the post. sup. vein, which could be found in the dorsocaudal wall of the portal vein within 2.5 cm from the confluence of the superior mesenteric and splenic vein (in the following text called confluence). After successful manipulation of the guide wire into the post. sup. vein the catheter was pushed over it.

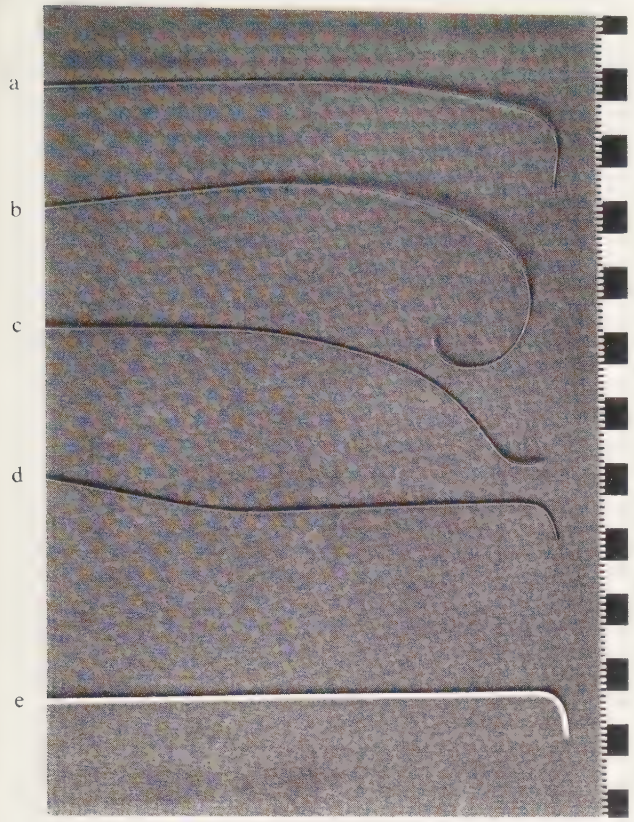


Fig. 2. Various shapes of guide wires used for selective catheterization of a) post. sup. vein, b) ant. sup. vein, c) transverse pancreatic vein, d) veins of the tail. e) Shape of catheter used for catheterization of veins of the tail, side-hole close to the tip.

During fluoroscopy a small amount of contrast medium was injected to assure a correct position of the catheter. After having emptied the contrast medium out of the catheter a blood sample could be withdrawn.

A phlebography was performed to document the place of blood sampling and to chart the venous anatomy. Into a post. sup. pancreaticoduodenal vein of normal caliber about 6 to 8 ml of contrast medium was injected by hand. Eight films were exposed, 2 films/s. In general, several adjacent veins, of the head of the pancreas and the inflow of the ant. sup. and inferior veins into the main tributaries of the portal vein system were demonstrated on these films (Fig. 3). Knowing the topography of the veins an adequate shape of the guide wire could be formed and catheterization was facilitated. Catheterization of the ant. sup. vein demanded in general an almost circular shape of the tip of the guide wire with a diameter of about 3 to 4 cm (Fig. 2b).

The transverse pancreatic vein was searched for in the left lateral wall of the superior mesenteric vein near the confluence, in the left lateral wall of the inferior mesenteric vein or caudally in the splenic vein near the confluence. An example of a usable shape of the guide wire for catheterization of this vein appears in Fig. 2c.

The main veins of the body were often demonstrated when contrast medium was injected into a pancreatic vein draining to the splenic vein. Thus, knowing their course, selective catheterization of these veins could usually be made (Fig. 4).

The veins of the tail of the pancreas usually can be entered in the ventrocaudal circumference of the splenic vein using a 1 to 1.5 cm long curve at the tip of the guide wire (Fig. 2d). Sometimes the guide wire slips out of the vein when the catheter is pushed over it. In these instances it can be helpful to preshape the catheter with an about 1 cm long curve (Fig. 2e). For catheterization of the veins of the tail the 25 cm long catheter as a rule had to be replaced by a 40 cm long one. In corpulent patients sometimes even catheterization of the ant. sup. pancreaticoduodenal vein demanded the longer catheter.

Blood sampling and injection of contrast medium in small pancreatic veins was facilitated by a side-hole close to the tip (Fig. 2e).

The amount of contrast medium used for filling of the veins of the body and tail depended on the size of the vessels and varied between 2 and 8 ml. All injections were made by hand.

Blood sampling technique

After 8 to 10 hours of fasting, catheterization of the coeliac artery, hepatic veins and portal vein was performed.

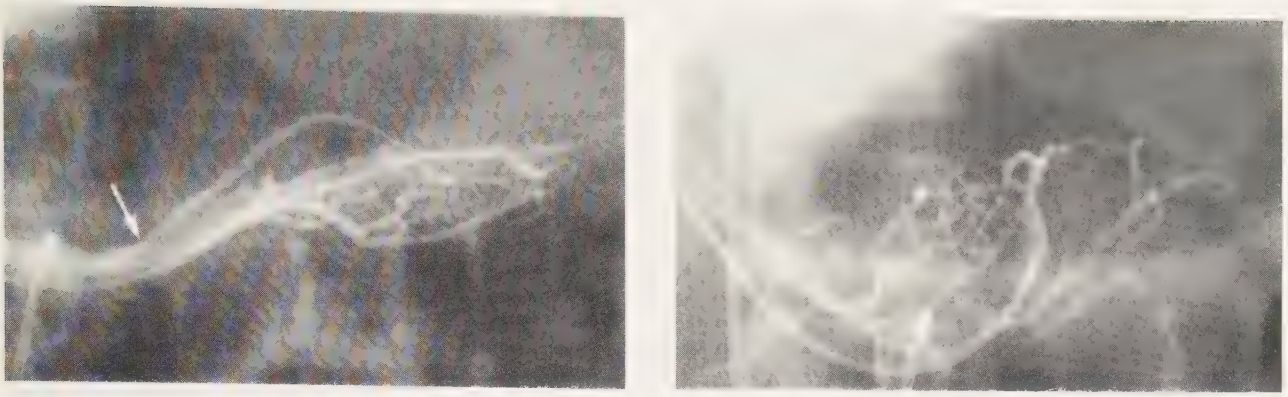
Samples were taken from all 3 catheters at the beginning and the end of the examination, sometimes even once more during the catheterization procedure. In the portal vein system samples were withdrawn at 2 or 3 levels of the splenic, superior mesenteric, and portal veins.

Selective catheterization of the post. and ant. superior pancreaticoduodenal vein and the transverse pancreatic or corresponding vein of the body and one or two veins of the tail was always aimed at. At the beginning when the knowledge of pancreatic vein topography was limited the success rate of selective catheterization was about 2 veins per examination. Later examinations comprised 4 to 6 selectively catheterized pancreatic veins. In smaller

c

d

Fig. 3. Selective selective catheterization in a patient with unusual anatomy. a) Injection into post. sup. vein. Via collaterals filling of ant. sup. vein which drains to the right branch of a double sup. mesenteric vein. Ant. inf. vein (→). Post. inf. vein (↔) ending in the left branch of the double sup. mesenteric vein (↠). b) Injection into ant. sup. vein. Via collaterals filling of post. sup. vein and veins of hepatoduodenal ligament. c) Injection into ant. sup. vein, the catheter more caudally directed. Gastroepiploic vein (→), vein to the right colon (↔) and ant. inf. vein (↠) filled. d) Injection into ant. inf. vein. Filling of ant. sup. (→) and post. inf. (↔) veins.



a b

Fig. 4. Same case as in Fig. 3. a) Injection into a vein of the tail draining to splenic vein. Inflow of a vein of the body (→). b) Injection into this vein of the body results in filling of other veins of the body, which have an unusual location cranial to the confluence. Veins of the body are draining to the cranial circumference of the region of the confluence.

pancreatic veins blood samples could not be withdrawn but were obtained by dripping. From the portal vein system 8 to 30 blood samples were taken for hormone assay.

Angiography

In all cases an examination including simultaneous coeliac and superior mesenteric artery injection, superselective injections of the gastroduodenal or common hepatic artery and splenic artery were aimed at but performed only in 14. In one of these even the dorsal pancreatic artery was examined. In 12 patients the coeliac, superior mesenteric and either gastroduodenal or splenic or inferior pancreaticoduodenal artery was injected. In 5 patients only coeliac and superior mesenteric angiography was obtained due to anatomic conditions or morphologic abnormalities, such as coeliac artery stenosis which made more selective catheterization impossible.

Radioimmunologic techniques

Blood samples for radioimmunoassay of gastrin, vasoactive intestinal polypeptide, and insulin were collected, centrifuged and sera were stored at −20°C until assayed. Blood samples for radioimmunoassay of glucagon and somatostatin were collected in tubes containing trasylol and heparin (for references see INGEMANSSON).

Surgery

At exploratory laparotomy the pancreas was palpated and inspected carefully. Dissection was performed in a way that the pancreatic veins could be identified and compared to the phlebographic findings. Resections of the pancreas were performed according to angiographic findings, the venous and phlebographic anatomy as well as the arteriovenous hormone differences.

Tissue analysis. Tissue specimens obtained at surgery were processed for immunocytochemistry (for references see INGEMANSSON).

Results

Angiography

Two of 5 insulin-producing tumours were correctly demonstrated at angiography. In one case a hypervascular lesion 1 cm in diameter in the body and

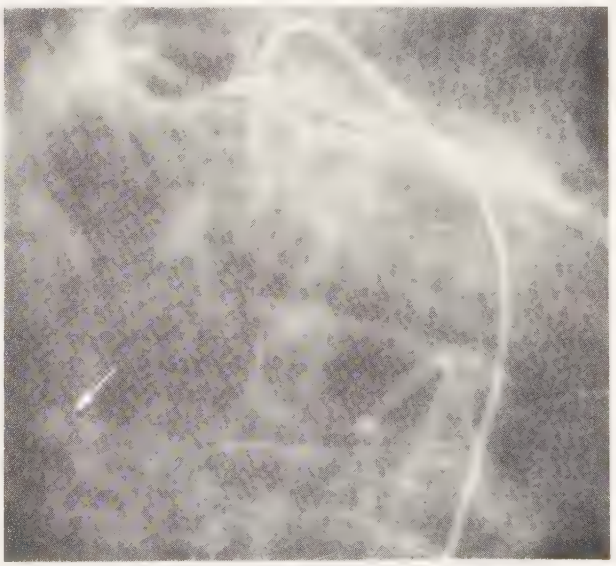


Fig. 5. Glucagonoma of the head of the pancreas. Injection into gastroduodenal artery, parenchymal phase. Small hypervascular lesion (→).

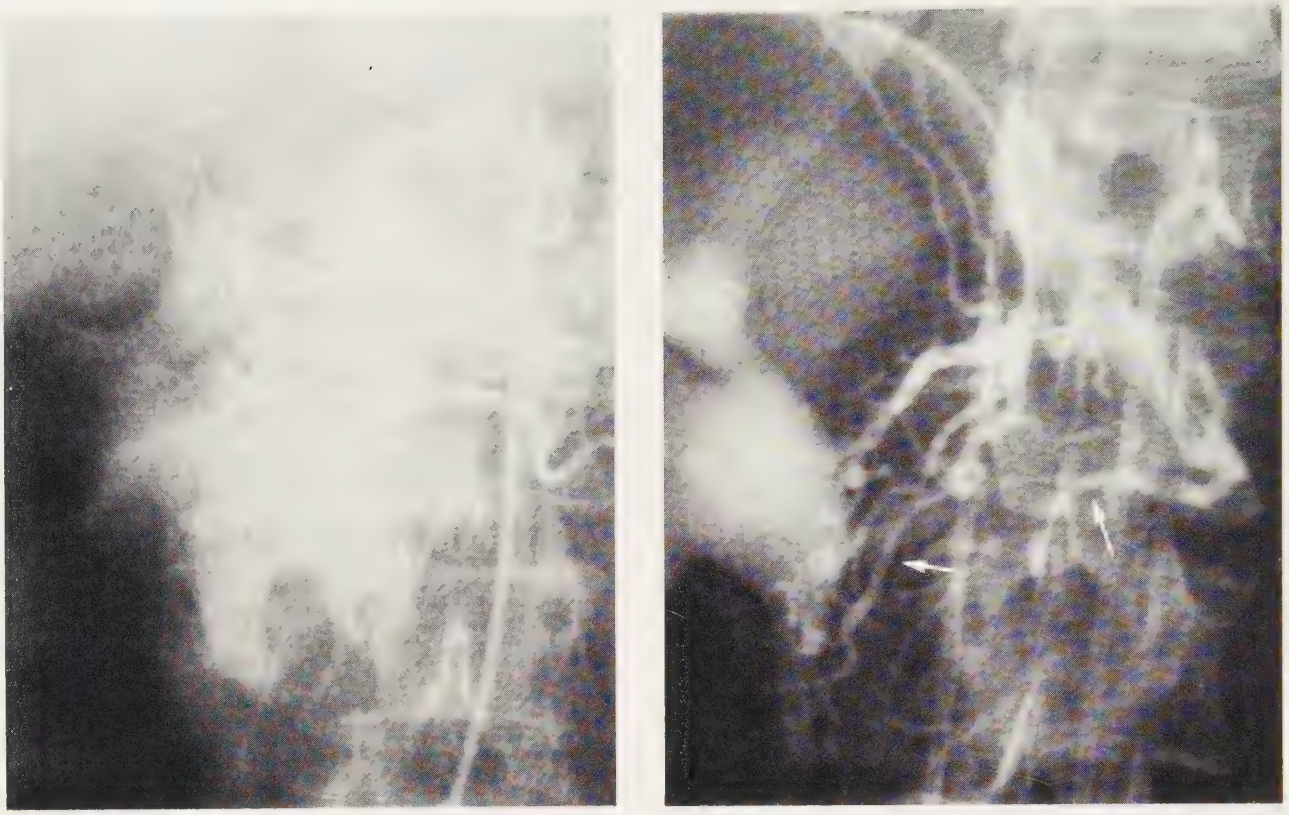


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Fig. 6. Tumour of the head of the pancreas, 5 cm in diameter. a) Injection into the common hepatic artery, parenchymal phase. b) Phlebography of the head. Slight curved displacement of the veins (→).

furthermore a hypervascular lesion in the hilum of the spleen were found. The latter was correctly considered as an accessory spleen. In the other case a hypervascular lesion adjacent to an avascular expanding lesion with a diameter of 10 cm was found. The latter turned out to be a cyst. No angiographic abnormality was found in 3 patients with insulinomas and in 2 patients with B-cell hyperplasia.

In 3 patients with multiple gastrin-producing tumours, angiography revealed one tumour (1.5 cm×2.5 cm) in one patient, two 6 mm large tumours in the second patient and was suggestive of further two 3 mm large tumours. No abnormality was found in the third patient. In the fourth patient, with Zollinger–Ellison syndrome, a 1.5 cm hypervascular lesion was demonstrated in the body of the pancreas. The patient refused surgery and thus the tumour is not confirmed.

In 3 patients with glucagonoma syndrome the tumours were located by angiography in 2. The size of the tumours was 5 cm and 4 cm, respectively. in the third patient a hypervascular lesion, 6 mm in diameter, in the head of the pancreas was found retrospectively (Fig. 5).

In one patient with a 9-year history of diarrhoea, a hypervascular tumour, 6 cm in diameter, was demonstrated in the head of the pancreas. This tumour contained and released somatostatin.

In one patient with heredity for multiple endocrine adenomatosis and previously operated upon for parathyroid adenoma, a hypervascular tumour, 2 cm in diameter, was demonstrated. At surgery this tumour and an additional tumour, 4 mm in diameter, were found. These tumours could not be classified by immunocytochemistry but were classified as D_1-cell tumours by electron microscopy.

In 15 patients without confirmed tumours, the angiography was normal.

Phlebography

Three tumours, 4, 5, and 6 cm in diameter, as well as the cyst, 10 cm in diameter, could be demonstrated as expanding lesions with displacement of the veins (Fig. 6). The other tumours were less than

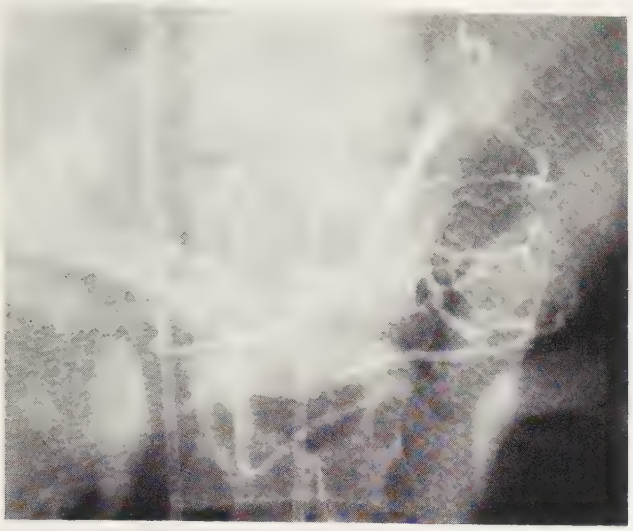


Fig. 7. Selective phlebography of the body of the pancreas in a patient in whom the tail has been resected. No morphologic abnormality.

2 cm in diameter and were not observed at phlebography. In one patient previously operated upon a branch from the ant. sup. pancreaticoduodenal vein was obliterated, probably ligated.

At postoperative examinations in patients with enucleated islet cell tumours, no morphologic abnormalities were demonstrated. In patients with hemipancreatectomy only ligation of the splenic vein was found and no abnormalities at selective phlebography of the remaining pancreatic tissue (Fig. 7).

Hormone analyses

Detailed results of hormone analyses have been published previously (INGEMANSSON et coll. 1975, 1977, 1978, REICHARDT et coll. 1979) and are therefore only summarized here.

Insulin-producing tumours and islet cell hyperplasias. Seven patients, 2 with B-cell hyperplasia and 5 with B-cell adenomas, were examined. In 2 patients islet cell hyperplasia in the tail and in the body of the pancreas, respectively, was correctly located by arteriovenous insulin concentration gradients. In 3 of 5 patients with B-cell adenomas the tumours were correctly located, 2 in the body and one in the tail of the pancreas.

In one patient with hyperinsulinism, operated upon twice with partial resection of the pancreas and ligation of the splenic vein, high insulin concentration was found in an anastomosing vein between the hilum of the spleen and the superior mesenteric vein. At laparotomy, an insulinoma was found in the remaining part of the tail. In one patient with an insulinoma in the dorsocranial part of the head of the pancreas the tumour could not be located by arteriovenous hormone differences though the sampling procedures were performed twice.

Gastrin-producing tumours. Four patients with Zollinger–Ellison syndrome were examined. In 2 the gastrin concentration was increased in general in the portal vein system and the analyses could not locate the tumours. At operation performed within 6 weeks after sampling multiple tumours were found within and around the pancreas. In one patient 2 examinations were performed after total gastrectomy and enucleation of a gastrinoma; gastrin concentrations were normal. An examination 4.5 years after gastrectomy revealed increased gastrin concentrations, in all veins in the region of the pancreas with a maximum in the post. sup. pancreaticoduodenal vein. At operation one tumour in the head, 1 cm in diameter, and multiple small tumours in the body and tail were found. In one patient all gastrin concentrations were increased with a maximum in the post. sup. vein. The patient refused surgery.

Glucagon-producing tumours. Three patients with glucagonoma syndrome were examined. All glucagon-producing tumours were correctly located by arteriovenous hormone gradients, 2 in the head and one in the tail of the pancreas. In one patient with a tumour in the head of the pancreas, the tumour even contained insulin and serotonin, and, furthermore, insulin concentrations were increased in the veins of the tail. Resection of the tail was performed. No hyperplasia or adenoma was found at light microscopy. Parts of the tissue were also examined by electron microscopy and immunochemistry, even then without pathologic findings.

Other tumours. One tumour of the head of the pancreas could not be classified preoperatively. Postoperative analyses proved that the tumour secernated somatostatin and localization of the tumour by arteriovenous somatostatin concentration differences was possible. One islet cell tumour could not be localized by the hormones analysed but could be classified as a D_1-cell tumour by electron microscopy.

Postoperative examinations. Six patients in whom resection of the pancreas had been performed were catheterized postoperatively, 3 of them twice.

In 3 patients, in whom adenomas had been enu-

Table

Hormone concentrations in tumour draining veins compared with the portal vein tributary outside the tumour draining veins

	Hormone concentration		Range of concentrations in the main portal vein tributaries
	In tumour draining vein	In main portal vein tributary at tumour level	
	μU/ml	μU/ml	μU/ml
Insulinomas			
1	–	865	93–260
2	600	300	13– 58
3*	1 130	45	11–165
4*	245	14	11– 68
5	6 200	179	14– 28
6	974	95	95–230
	pg/ml	pg/ml	pg/ml
Glucagonomas			
1	24 000	2 900	1 320–2 400
2	10 000	800	600–1 750
3	10 650	?	856–2 213

* B-cell hyperplasia

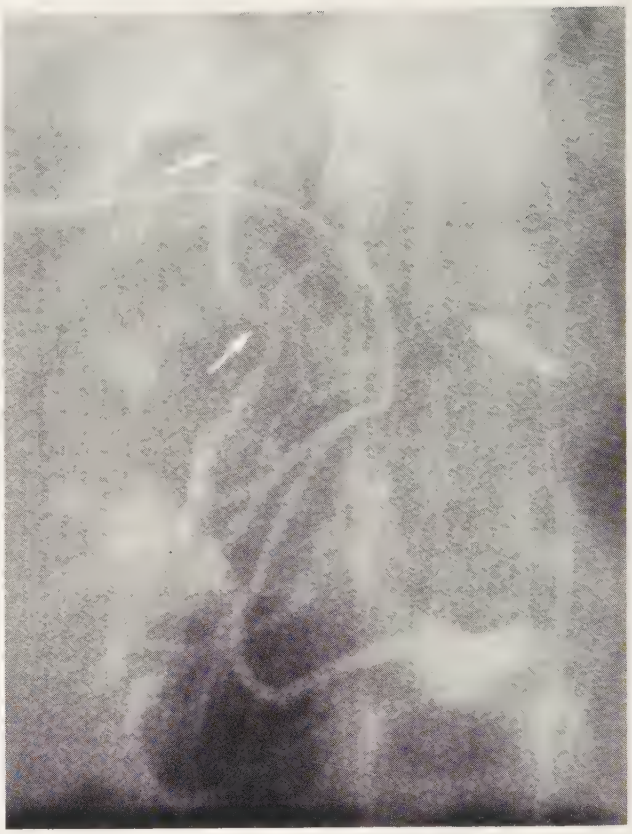


Fig. 8. Insulinoma of the head of the pancreas. The hormone analyses could not locate the tumour. Injection into ant. sup. vein reveals a venous connection between the head of the pancreas and the left lobe of the liver (→).

cleated, postoperative triple catheterization was performed, in one of them twice.

In one patient with Zollinger–Ellison syndrome, recurrence was suggested which was confirmed operatively. A recurrence was suggested also in one patient operated upon for a glucagonoma but the patient refused further investigations and operation.

Value of selective catheterization. Three insulin-producing islet cell tumours could have been located by blood sampling in the main tributaries of the portal vein system (Table). The islet cell hyperplasia had not been located without selective catheterization of pancreatic veins. In one patient with glucagonoma the location of the tumour could only have been suggested and one had been missed without selective examination. In one case no sample was withdrawn outside the tumour draining vein.

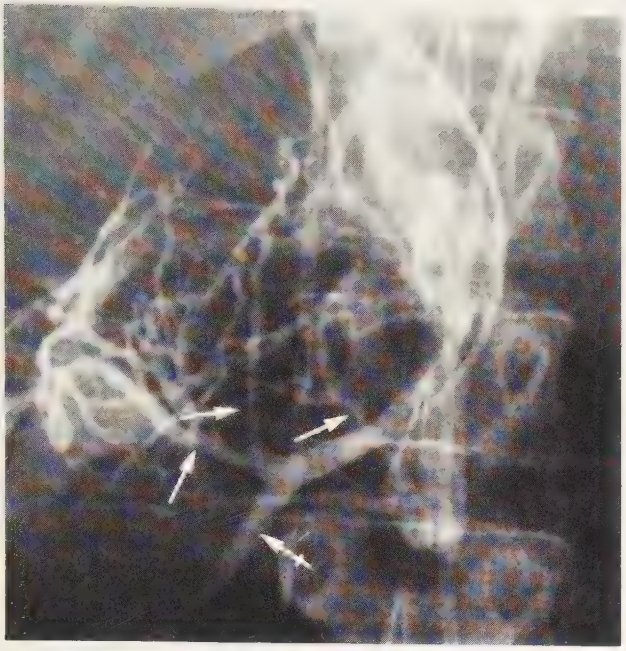
Complications

In one patient abdominal pain and fever followed accessory puncture of the gallbladder. The condition was normalized after 2 days. In one patient a 7 cm×12 cm hematoma in the right lobe of the liver developed after percutaneous transhepatic portography. No specific treatment was needed.

Discussion

Angiography is regarded as the method of choice for localization of islet cell tumours of the pancreas. The reported accuracy in localization of insulinomas varies widely. In a review of 170 cases of the literature STEFANINI et coll. (1974) found a success rate of 66 per cent. All islet cell tumours producing hormones known today have the same angiographic appearance. The accuracy of angiography in localization of other tumours than insulin-producing is not known as the number of reported cases is too small.

Gastrinomas are often multiple and in the present series it was not possible to demonstrate all the tumours in one patient by angiography. Neither was it possible to locate multiple gastrinomas by portography and hormone analyses. Generally elevated gastrin concentrations were certainly suggesting multiplicity of gastrin releasing tumours but could not locate these tumours. Total gastrectomy has been the accepted method of treatment in patients



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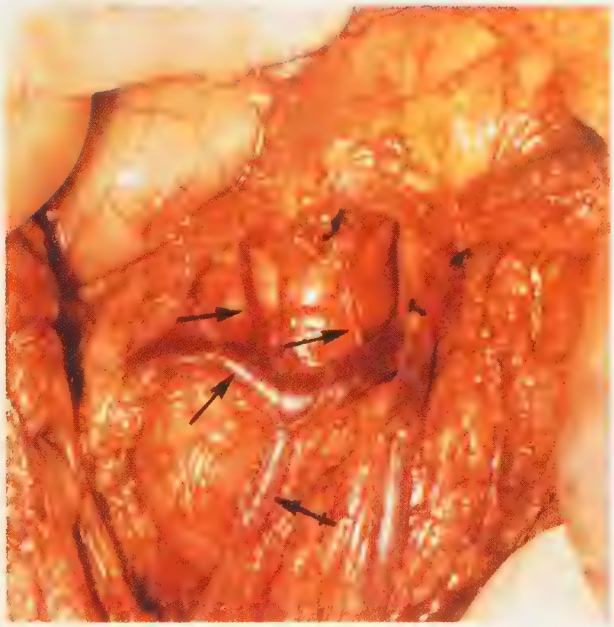

b

Fig. 9. Phlebographic anatomy can be identified during operation. a) Phlebography of the head. Injection into ant. sup. vein. Colon vein (↔), ant. sup. branches (→). b) Veins of the head of the pancreas after dissection in situ. Colon vein (↔), ant. sup. branches (→).

with Zollinger–Ellison syndrome. The recently introduced histamin H_2-receptor antagonists (STAGE et coll. 1976, BONFILS et coll. 1977) have raised new possibilities. If an accurate preoperative localization of gastrinomas can be obtained, extirpation of the tumours and resection of the antrum of the stomach and duodenum will be the therapy of choice. In patients with multiple gastrinomas, which cannot be located, treatment with H_2-antagonists should be tried.

All glucagon-producing tumours could be demonstrated by angiography. In one patient with a glucagonoma of the head of the pancreas, which even released insulin and serotonin, high insulin concentrations were found in a vein of the tail. These concentrations were 7 to 10 times higher than the insulin concentration of the main portal vein tributaries, strongly indicating that an adenoma or B-cell hyperplasia was present in the tail even if it was not demonstrated by immunocytochemistry.

In one patient with an insulinoma of the head of the pancreas neither angiography nor hormone analyses could locate the tumour. The failure of triple catheterization was due to an unusual anatomy of the veins of the head of the pancreas. Injection of the post. sup. pancreaticoduodenal vein as well as the ant. sup. vein revealed a vein of the hepatoduodenal ligament between the head of the pancreas and the hilum of the liver, probably draining a cranial part of the head directly to the portal vein branches of the left lobe of the liver (Fig. 8).

Very small islet cell tumours and islet cell hyperplasia cannot be located by angiography. In these cases selective catheterization of the pancreatic veins was necessary for localization of the lesions as the hormone concentrations in the splenic vein at the level of inflow of the draining vein were not elevated as compared to other samples.

The accuracy of both angiography and triple catheterization was in the present series higher than of one method alone. If possible both angiography and triple catheterization should be performed for preoperative localization of endocrine pancreatic tumours. The rate of angiographic false positive diagnoses of 60 reported investigations for suggested insulinomas was 11 per cent (KOROBKIN et coll. 1971). In one case of the present material an accessory spleen was demonstrated at angiography. Angiographic differentiation between an accessory spleen and an islet cell tumour is sometimes impossible.

In patients with hyperinsulinism or glucagonoma syndrome with positive angiographic findings, however, only in one of six cases unexpected high

insulin concentrations were found at another location than the angiographically demonstrated tumour. The number of patients is small and it is possible that multiple endocrine disturbances in the same pancreas are more common.

If blood sampling for hormone assay is performed, the examination should include selective catheterization of the pancreatic veins, especially if angiography did not locate a tumour. Islet cell hyperplasia and even adenomas can be missed if only sampling at different levels in the main tributaries of the portal vein is performed (Table).

Furthermore, there was no evidence of increased complications if selective examinations of the pancreatic veins were performed. The complication risk was obviously correlated to the percutaneous puncture of the portal vein, not to selective catheterization of the veins.

Phlebography of the pancreatic veins was necessary for proper documentation of the places of blood sampling. Knowledge of the individual venous anatomy was important for evaluating hormone concentration differences. By dissection of the veins during operation (Fig. 9), according to the phlebographic anatomy and the hormone concentrations of the sampled blood, an occult adenoma and islet cell hyperplasias were found.

Selective catheterization of the pancreatic veins in an extensive manner as aimed at in blood sampling for hormone assay seems only possible using the percutaneous transhepatic approach to the portal vein. The transumbilical approach implies a course with several curves and angles which makes selective catheterization of veins of the body and tail hazardous and difficult.

SUMMARY

Based on 45 examinations the technique of selective catheterization of the pancreatic veins for blood sampling using the percutaneous transhepatic approach to the portal vein is described. The results are compared with the angiographic findings in 16 patients with islet cell tumours or islet cell hyperplasia.

ACKNOWLEDGEMENTS

Immunocytochemistry was performed by Dr L. I. Larsson, Institute of Medical Bio-Chemistry, University of Aarhus, Aarhus, Denmark. Insulin determinations were performed by Dr C. Kühl, Department of Internal Medicine T, Bispebjerg Hospital, Copenhagen, Denmark. Glucagon determinations were performed by Dr J. Holst, Department of Clinical Chemistry, Bispebjerg Hospital, Copenhagen, Denmark. Gastrin determinations were performed by Dr F. Stadil, Department of Surgery, Herlev Hospital, Copenhagen, Denmark.

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SELECTIVE PHLEBOGRAPHY IN PANCREATIC AND PERIPANCREATIC DISEASE

W. REICHARDT

Selective phlebography of the pancreas in vivo was first reported by GÖTHLIN et coll. (1974). Pancreatic veins were accidentally found available for selective catheterization in cases where portography was performed for examination of the liver. Most of the cases were examined using the transumbilical approach to the portal vein. Later on when more interest was paid to selective catheterization of portal vein tributaries (LUNDERQUIST & VANG 1974, LUNDERQUIST et coll. 1977, 1978, HOEVELS et coll. 1978, REICHARDT et coll. 1979) the percutaneous transhepatic approach was preferred as it facilitated the catheterization procedure. Pancreatic phlebography was found to be a useful diagnostic method in carcinoma of the pancreas (REICHARDT et coll. 1978) and—combined with blood sampling for hormone assay—in endocrine tumours of the pancreas (INGEMANSSON 1977, LUNDERQUIST et coll. 1978).

In recent years several new methods for evaluation of pancreatic morphology, such as endoscopic retrograde cholangiopancreaticography (ERCP), ultrasound and computer tomography, have been developed and improved. These have now, with the exception of localization of islet cell tumours, replaced angiography as the dominating diagnostic radiologic method in examination of the pancreas.

The present report constitutes an analysis of the morphologic abnormalitites observed at selective phlebography in patients with pancreatic and peripancreatic disease and a discussion of its clinical value.

Anatomy of the pancreatic veins. The phlebographic anatomy of the pancreas has been described in detail previously (REICHARDT & CAMERON 1980) and only a short summary is now given.

The veins of the pancreas may drain to all the main portal vein tributaries adjacent to the organ. The dorsal aspect of the head of the pancreas is mainly drained by one or two posterior superior pancreaticoduodenal veins ending into the portal vein (Fig. 1 in REICHARDT & INGEMANSSON 1980). Sometimes also a dorsal pancreatic vein is found emptying into the confluence of the superior mesenteric vein and the splenic vein (in the following text called confluence). The dorsocaudal part is often drained by the posterior inferior pancreaticoduodenal vein to the superior mesenteric vein or to the first jejunal vein.

The ventral aspect of the head of the pancreas is drained by the anterior superior pancreaticoduodenal vein which empties into the superior mesenteric vein after having joined the gastrocolic trunk. The veins of the ventrocaudal part of the head are collected in the anterior inferior pancreaticoduodenal vein which ends in the superior mesenteric vein or—together with the post. inf. vein in the first jejunal vein. The main veins of the head are connected by collaterals which sometimes run in the ventral and dorsal furrow between the head of the pancreas and the duodenum forming a ventral and a dorsal arcade. The body of the pancreas is drained by the transverse pancreatic vein which ends in the inferior mesenteric vein, the superior mesenteric vein or the splenic vein. Some veins of the body

Submitted for publication 16 August 1979.

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often run to the left gastric vein. The veins of the tail of the pancreas usually drain to the splenic vein.

All the mentioned veins of the head of the pancreas and their closest branches towards the duodenum as well as the main part of the transverse pancreatic vein are situated on the surface of the organ. The intrapancreatic veins are small and connect the main stems on the surface. Veins of the tail and body draining to the splenic vein are mainly intrapancreatic.

Material and Methods

Since 6 years selective phlebography of the pancreas was performed in 67 patients (26 women, 41 men) with proven disease in the pancreaticoduodenal region. The age ranged from 21 to 85 years.

In 50 patients the indication for examination was possible malignancy of the pancreas. Forty-three patients were referred with obstructive jaundice, in 2 patients a tumour in the region of the head of the pancreas was found at cholecystectomy and the patients were referred for evaluation of resectability. Five patients with chronic pancreatitis were examined because scintigraphy of the pancreas, ERCP or ultrasound had suggested malignancy. The final diagnoses in this group were carcinoma of the head of the pancreas in 35 patients, carcinoma of the extrahepatic bile ducts in 9, chronic pancreatitis in 5, and retropancreatic malignant lymphoma in one patient. The diagnoses were confirmed at microscopy in all patients with tumours and by the clinical course during at least 14 months observation in patients with chronic pancreatitis. Laparotomy was performed in 2 patients with pancreatitis.

In 17 patients the examination was performed for diagnosis and localization of endocrine tumours of the pancreas. The final diagnoses in this group were gastrinomas (4 patients), glucagonomas (3), insulinomas (5), islet cell hyperplasia causing hyperglycemia (2), and somatostatinoma (1). In one patient the tumour could not be classified by immunocytochemistry but was classified as D_1-cell tumour at electron microscopy. One patient had no islet cell tumour but multiple submucosal lipomas of the duodenum. The diagnoses were confirmed at surgery in all patients but one with a Zollinger–Ellison syndrome who refused surgery.

The tumour size was defined in situ and in the operative specimen. If no resection was performed the size was estimated at laparotomy.

Percutaneous transhepatic puncture of the portal vein was performed with a 25 cm long needle sheathed with a polyethylene catheter (OD 1.6 mm, ID 1.0 mm; Surgimed, Denmark). The puncture technique was introduced by WIECHEL (1971) and has been described previously (GÖTHLIN et coll., HOEVELS et coll.). The pancreatic veins were catheterized using a 0.9 mm guide wire with a soft tip and the catheter was pushed over the guide wire into the vein. A detailed description of the technique of selective catheterization of the pancreatic veins is given elsewhere (REICHARDT & INGEMANSSON).

For examination of the main stems of the portal vein system and the parenchyma of the liver 40 ml of contrast medium (Isopaque Coronar, 370 mg I/ml, Nyegaard, Norway) was injected at a rate of 8 ml/s. Sixteen films were exposed (5 films/5 s, 8 films/4 s, 3 films/6 s).

Pancreatic phlebography was performed by manual injection of 2 to 10 ml of contrast medium—depending on the size of the vessels—and 8 films (2 films/s) were exposed.

When the examination was performed to demonstrate or to rule out a carcinoma of the head of the pancreas the catheterization was limited to the area of interest. As a rule only one of the main veins of the head—the ant. sup. or post. sup. pancreaticoduodenal vein—was injected. In 5 cases both the ant. sup. and post. sup. veins, in 3 cases the post. sup. vein and the dorsal pancreatic vein and in one case the ant. sup., post. sup. and transverse veins were examined.

In patients with endocrine tumours catheterization of the veins of the entire pancreas was aimed at for blood sampling. Only phlebographies of the part of the pancreas containing an islet cell tumour or hyperplasia will be discussed in the following.

Results

Carcinoma of the head of the pancreas. In 5 of 35 patients with pancreatic carcinoma the selective phlebographies could not be evaluated due to extravasation of contrast medium in 2 patients and incomplete filling of pancreatic veins due to inadequate position of the catheter in 3. In 4 patients neither the ant. sup. nor the post. sup. pancreaticoduodenal veins could be entered with the catheter. At the expected position of their orifice an irregulari-

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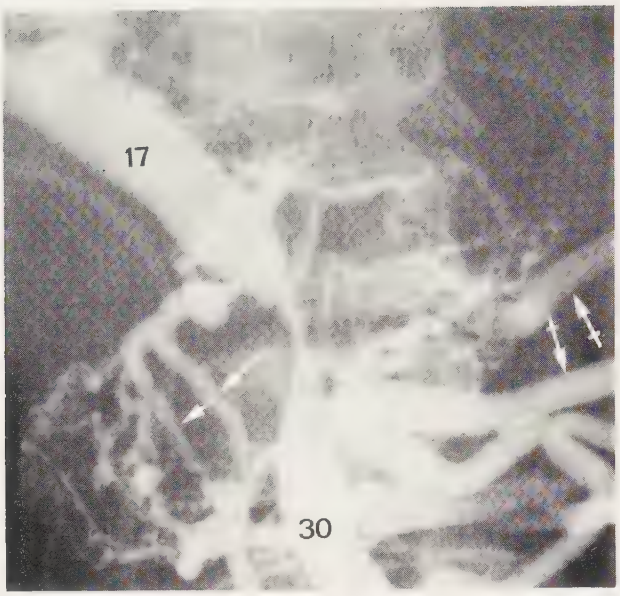
Fig. 1. Female aged 49 years with a 7 cm non-resectable carcinoma of the head of the pancreas. Injection into ant. sup. pancreaticoduodenal vein. a) A. p. view. Occlusion of multiple veins of the head of the pancreas (→). Irregularity of veins in the tumour area (↔). No flow of contrast medium to post. sup. pancreaticoduodenal vein, which probably is occluded. b) Lateral view. Anterior displacement of sup. mesenteric vein near the confluence (↔). Veins posterior to portal vein are occluded (→).

Fig. 2. Male aged 50 years with a 5 cm non-resectable carcinoma of the head of the pancreas. Injection into post. sup. pancreaticoduodenal vein. Occlusion of posterior pancreatic veins (→). No demonstration of main anterior veins.



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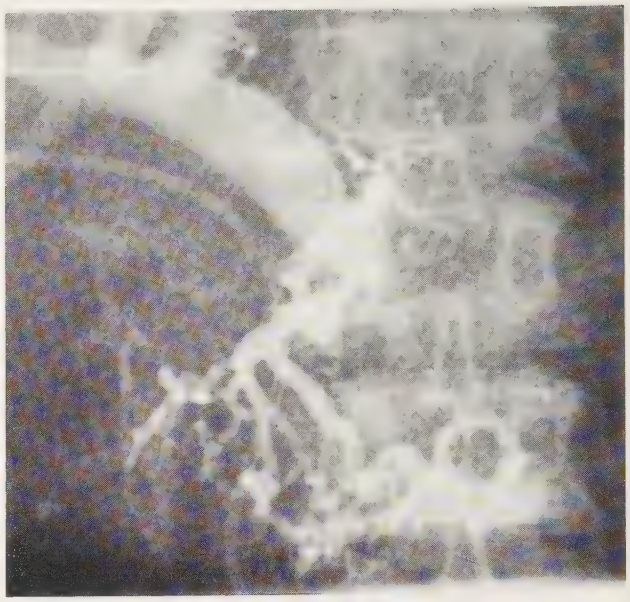

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Fig. 3. Male aged 70 years with a non-resectable carcinoma of the head of the pancreas. a) Injection into sup. mesenteric vein. Severe stenosis of the confluence with a pressure gradient of 13 cm H_2O. Collateral flow via pancreaticoduodenal veins (→) and veins of the transverse colon (↔). b) Injection into post. sup. pancreaticoduodenal vein. Only filling of the collateral veins on the surface of the pancreas.

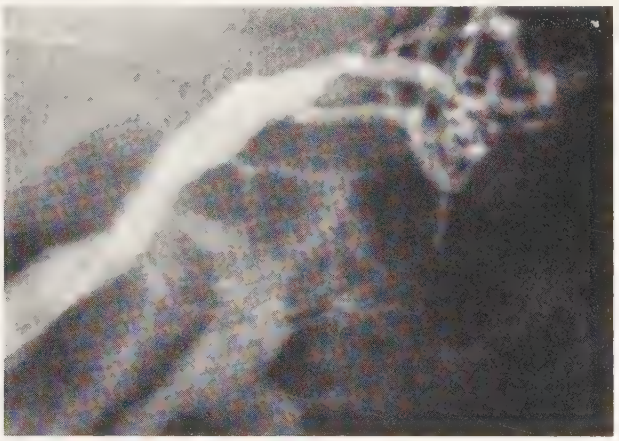

Fig. 4. Male aged 69 years with an islet cell tumour (malignant glucagonoma) of the tail of the pancreas 4 cm in diameter. The tail is widened, the veins are slightly dilated and displaced. The splenic vein is irregular.

ty of the vessel wall could be felt when catheterization was tried. Laparotomy in these cases revealed irresectable carcinoma 6 to 10 cm in diameter.

In 20 patients with carcinoma of the head of the pancreas, 4 to 10 cm in diameter, stenoses and occlusion of veins of the head could be demonstrated (Figs 1, 2). Widened collateral pancreaticoduodenal veins were found in 6 patients (Fig. 3). In all these cases severe encasement of the portal vein system in the region of the confluence was found and the widened pancreaticoduodenal veins were collateral pathways between the superior mesenteric and portal veins. Small pancreatic collaterals were only identified in 2 cases.

In one patient small pancreatic veins were probably occluded. At surgery a tumour 3 cm in diameter was found.

Patent pancreatic veins were found in all 5 patients with tumours 2 cm (4 cases) and 1 cm (1 case) in diameter, respectively. However, abnormal veins were demonstrated in 4 of the cases when the tumour was associated with inflammatory lesions in or around the head of the pancreas (Table). In one patient only pancreatitis with abscess formation was found at surgery but at autopsy 4 months later a 2 cm large carcinoma was found.

Islet cell tumours. Fourteen patients with islet cell tumours and 2 patients with islet cell hyperplasia were examined. The tumour size ranged from less than 1 to 6 cm. A cyst 10 cm in diameter in the tail of the pancreas adjacent to an islet cell tumour was found in one patient.

No phlebographic abnormalities were found in 11 patients with islet cell tumours 2 cm or less in diameter, nor in 2 patients with islet cell hypoplasia.

Displacement of the veins was observed in pa-

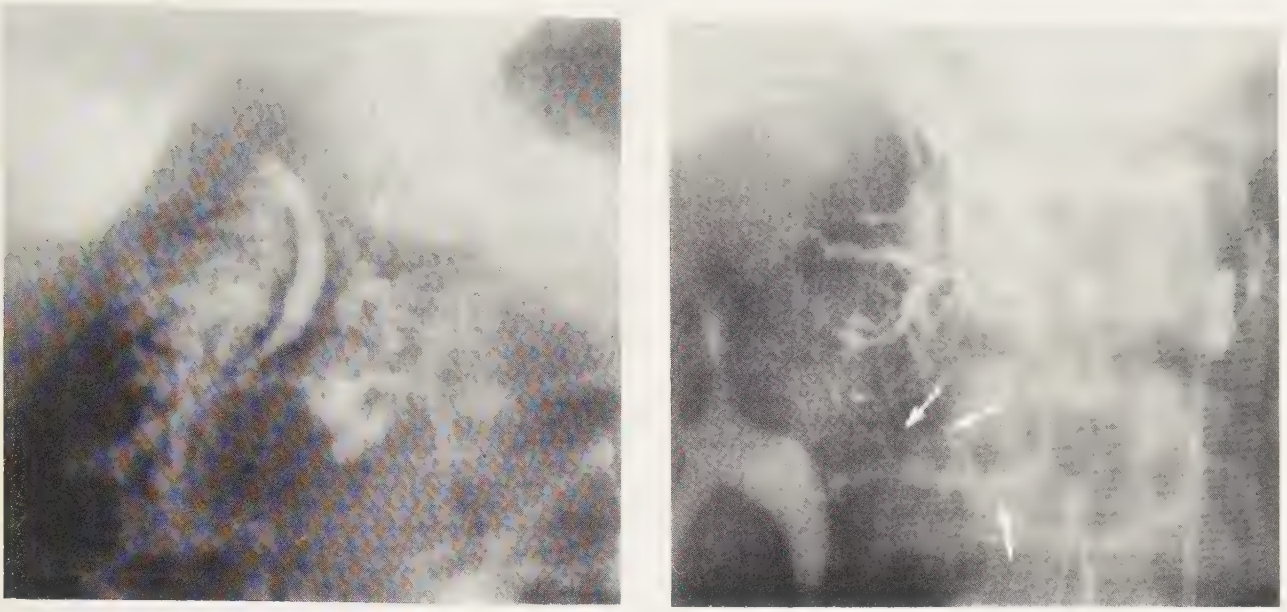

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Fig. 5. Male aged 51 years with chronic pancreatitis, multiple cystic lesions of the pancreatic duct and enlargement of the head of the pancreas. a) Ectatic parts of the duct and cysts are filled with contrast medium after ERCP. b) Injection into post. sup. pancreaticoduodenal vein. Irregular veins, partly stretched and displaced by cysts (→). Patent collaterals to ant. sup. pancreaticoduodenal vein (↔).

tients with islet cell tumours 4, 5 and 6 cm in diameter, respectively, and in the patient with the 10 cm large cyst. In the patient with a 4 cm large malignant glucagonoma widened pancreatic veins and an irregular splenic vein were demonstrated in addition (Fig. 4).

Pancreatitis. Five patients with chronic pancreatitis in whom the clinical course, ERCP, ultrasound, or pancreatic scintigraphy were suggestive of a pancreatic carcinoma were examined.

The veins were slender and irregular and changed their course abruptly. Collaterals between the ant. sup. and post. sup. pancreaticoduodenal veins were patent in 4 patients. The veins were stretched in regions where ERCP disclosed cysts (Fig. 5). In one patient the post. sup. vein was occluded, but small intrapancreatic veins were patent adjacent to the portal vein at the estimated position of this vein (Fig. 6). At laparotomy a pseudotumour of the head of the pancreas about 6 cm in diameter was found. Multiple fine needle biopsies revealed no carcinoma. A shunt between the tail of the pancreas and jejunum was performed and the patient has been well without signs of malignancy 18 months after surgery.

Engagement of the confluence was demonstrated in one patient. The vessel was irregular and a slight stenosis was present (Fig. 7). In one case the splenic vein near the confluence was slightly stenosed. In this patient pancreatitis was present in the entire pancreas.

Slender veins, either stretched or kinked, were also demonstrated in 2 patients with carcinoma of the head of the pancreas surrounded by pancreatitis and in one patient with carcinoma of the head of the pancreas and pancreatitis of the body.

Peripancreatic disease. Nine patients with carcinoma of the extrahepatic bile ducts (proximal to

Table

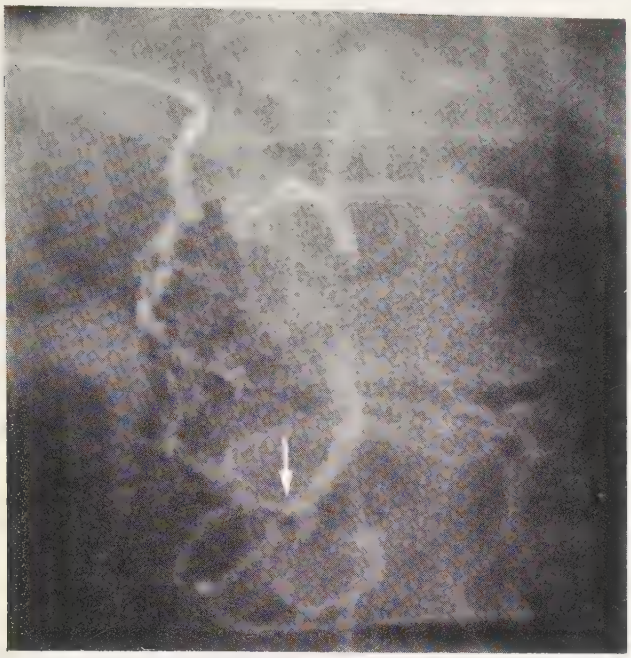
Phlebographic findings in 4 patients with carcinoma of the pancreas 2 or 1 cm in diameter associated with inflammatory lesions

Case No.	Surgery	Phlebography
1	Pancreatitis, abscess in and around the pancreas. A 2 cm tumour found 4 months later	Stretched, slender veins. No occlusion
2	Enlarged head, 1 cm tumour. Surrounded by pancreatitis	Slender, irregular veins abrupt changing their course. No occlusion
3	Layer of fibrotic tissue on the surface of the pancreas. A 2 cm tumour	Dilated, irregular veins on the surface. Normal intrapancreatic branches
4	A 2 cm tumour surrounded by fibrosis	Tiny, irregular veins in a 3 cm area. Otherwise normal and patent veins

Fig. 6. Male aged 37 years with chronic pancreatitis. At laparotomy an inflammatory pseudotumour (6 cm in diameter) of the head of the pancreas was found. The postoperative clinical course revealed no signs of malignancy after 18 months. a) Injection into ant. sup. pancreaticoduodenal vein. The veins of the head are slender, irregular, displaced. Small veins near the post. sup. pancreaticoduodenal vein are patent (→), post. sup. vein probably occluded. Right gastric vein (↦), middle colic vein (↠). b) Injection into the pancreatic duct during operation. Severe stenosis of the major duct in the head, displacement.

the pancreas), one patient with submucosal lipomas of the duodenum and one patient with retropancreatic malignant lymphoma were examined.

In one patient with cholangiocarcinoma no adequate demonstration of the veins of the pancreas was obtained. The veins of the pancreas were patent and without morphologic abnormalitites in 7 patients with carcinoma of the extrahepatic bile ducts. In one of these the choledochal veins were widened and tortuous and in another occluded (Fig. 8). The post.



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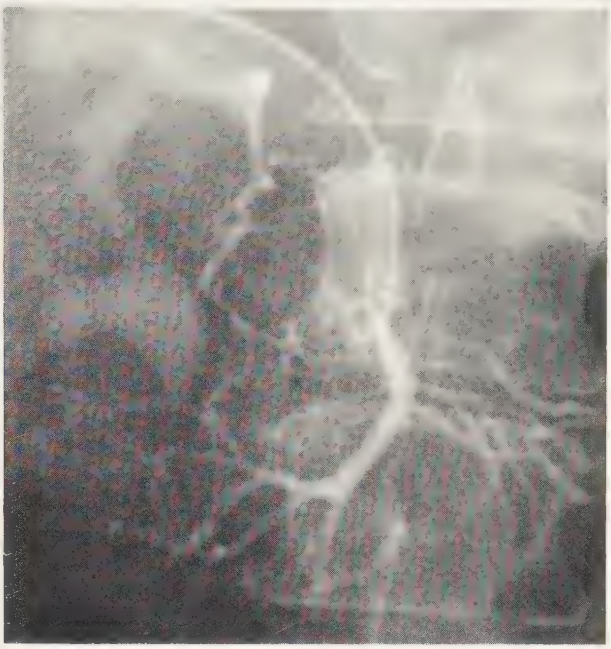

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Fig. 7. Male aged 67 years with chronic pancreatitis confirmed at laparotomy, needle biopsy and the postoperative course of 14 months. a) Injection into post. sup. pancreaticoduodenal vein. Irregular, slender veins but patent collaterals to ant. sup. pancreaticoduodenal vein (→). b) Injection into ant. sup. pancreaticoduodenal vein, post. sup. pancreaticoduodenal vein is filled. c) Severe wall irregularity and stenosis of the region of the confluence.

sup. vein was dilated and tortuous choledochal veins were present in one patient. Displaced and stretched peripheral branches of the pancreaticoduodenal veins were found in a patient in whom laparotomy disclosed submucosal duodenal lipomas (Figs 9, 10).

Patent but stretched veins of the head of the pancreas were demonstrated in a patient in whom prior laparotomy had disclosed a tumour mass in the head of the pancreas. No abnormality was found at needle biopsy during operation. The phlebographic findings confirmed an expansive lesion in this region but argued against a large pancreatic carcinoma as collaterals between the anterior and posterior veins were patent. Percutaneous needle biopsy guided by phlebography revealed malignant lymphoma, confirmed at a second laparotomy.

Complications. Extravasation of contrast medium occurred in 3 patients without causing discomfort to the patients. Two examinations were impossible to evaluate.

In one patient with chronic relapsing pancreatitis abdominal pain and anaemia occurred after the phlebography, probably due to bleeding. Serum amylase was normal but liver laboratory data pathologic. The patient was treated conservatively.

In one patient with islet cell tumour a subcapsular haematoma of the liver 7 cm×12 cm in diameter developed but no specific treatment was required.

In one patient with islet cell tumour abdominal pain and fever followed accidental puncture of the

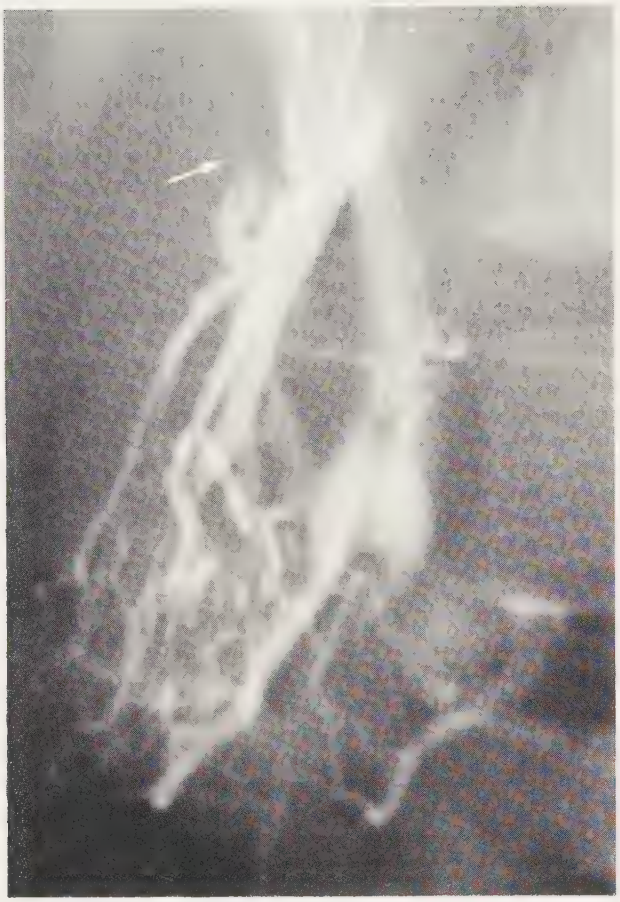


Fig. 8. Male aged 44 years with carcinoma of the gallbladder causing obstruction of the extrahepatic bile ducts in the hilum of the liver. Injection into post. sup. pancreaticoduodenal vein. Left anterior oblique veiw. Normal veins of the head of the pancreas. Obstruction of the choledochal veins (→).

Fig. 9. Male aged 21 years with multiple submucosal lipomas of the duodenum. Hypotonic duodenography.

gallbladder. The condition was normalized after 2 days.

Intraabdominal bleeding which required emergency laparotomy occurred in 2 patients. Both examinations were performed before 1974 when experience with percutaneous transhepatic puncture was still limited.

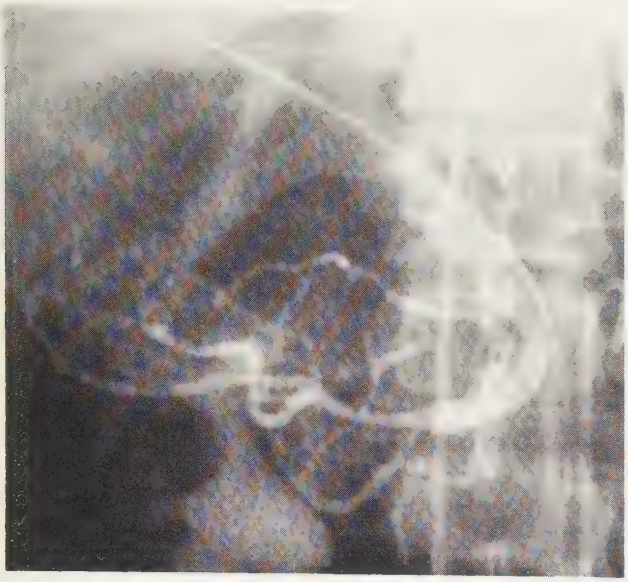
Discussion

When selective phlebography of the pancreas was introduced (GÖTHLIN et coll.) the hope was expressed that this method could be useful in the diagnosis of carcinoma of the pancreas since this tumour is apt to invade the veins early. The previously reported minimum size of carcinoma of the pancreas diagnosed by phlebography was 3 to 4 cm (REICHARDT et coll. 1978). These primary results were disappointing but confirmed in the present increased material.

The diagnostic phlebographic criteria for pancreatic carcinoma were irregular stenoses and obstruction of pancreatic veins with collateral flow. In the present material venous occlusion was the dominating diagnostic finding. The interruption of flow between anterior and posterior branches was often evident.

Irregular stenosis alone may, however, also be observed in patients with chronic pancreatitis. Collaterals were only demonstrated in 6 of 35 patients and in these cases due to stenosis of the superior mesenteric vein or the confluence and not due to obstruction of pancreatic veins. Small pancreatic collateral veins probably due to occlusion of pancreatic veins were only observed twice.

The explanation is probably to find in the pancreatic vein anatomy (REICHARDT & CAMERON): (1) The main veins of the organ are running on the surface, (2) the intrapancreatic veins are relatively small and (3) usually the head of the pancreas is drained by 4 main veins in 4 directions, and connections also exist to the veins of the body. If a carcinoma occludes a pancreatic vein its function will be taken over by another one since no valves exist.



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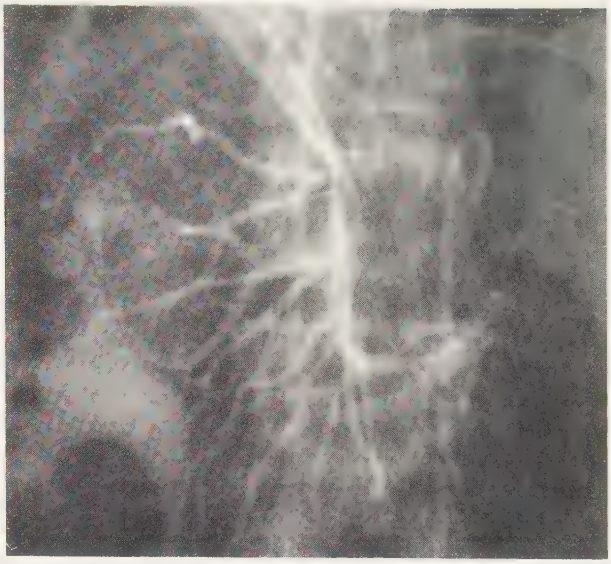

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Fig. 10. Same case as in Fig. 9. Injection into a) ant. sup. pancreaticoduodenal vein and b) post. sup. pancreaticoduodenal vein demonstrates stretched patent veins indicating an expanding lesion without obstruction of pancreatic veins.

The phlebographic anatomy also explains why tumours smaller than 3 to 4 cm probably cannot be demonstrated as the phlebographic appearance is dominated by the main veins on the surface of the organ. These veins superimpose on the minor intrapancreatic branches and it is improbable that any occlusion of these can be observed. Only when the tumour is growing to the surface of the organ can occlusion of the main branches be demonstrated. As the contrast medium is injected against the blood flow sometimes a false impression of venous occlusion is obtained. However, usually a proper evaluation of the whole series allows a differentiation between occlusion and flow phenomenon.

In patients with chronic pancreatitis the veins were abnormal with irregularity, abrupt changes of their course and slender appearance. The veins were stretched in cases with pancreatic cysts and abscess. Even in patients with severe inflammatory lesions the veins were generally patent.

The post. sup. pancreaticoduodenal vein was occluded in one case and a thrombotic wall irregularity in the region of the confluence was observed in another. These findings were in discrepancy to the patent intrapancreatic veins and therefore arguing against pancreatic carcinoma as the cause of the morphologic abnormalities.

The phlebographic findings thus allow differentiation between pancreatic carcinoma (larger than 3 to 4 cm) and chronic pancreatitis. The characteristic abnormalities in cases with carcinoma of the head of the pancreas are occluded veins in the area occupied by the tumour which as a rule result in absent flow between anterior and posterior pancreatic veins. In patients with chronic pancreatitis the veins are abnormal in various degrees but generally patent. Even if occlusion of veins occur a discrepancy between the localization of an occlusion and the patency of adjacent smaller veins allows a differentiation between chronic pancreatitis and a large carcinoma.

In recent years, computer tomography and ultrasound have been developed and at present improved to high sensitivity and specificity in evaluation of the morphology of the pancreas. Together with ERCP, percutaneous transhepatic cholangiography and percutaneous fine needle biopsy these methods will establish the diagnosis in patients with obstructive jaundice and suggestion of pancreatic malignancy and allow the differentiation between pancreatic carcinoma, pancreatitis and extrapancreatic lesions in the majority of cases.

In rare instances, when differentiation between pancreatic carcinoma and pancreatitis cannot be obtained by these methods, pancreatic angiography and phlebography may give valuable information. If a specific tumour marker in pancreatic carcinoma could be found, detection and localization of the tumour by pancreatic venous blood sampling and determination of the tumour marker might be possible.

When the diagnosis of a pancreatic carcinoma is established angiography and portography are useful for evaluation of resectability of the tumour (REICHARDT & IHSE 1980). Selective phlebography is in these cases irrelevant.

As expected, the value of selective phlebography in endocrine tumours for detection of morphologic abnormalities was limited. Most of the endocrine tumours are too small to be detected with this method. The value of phlebography in endocrine tumours is almost exclusively to document the venous anatomy in order to allow a correct interpretation of blood sample analyses. An interesting finding was dilated slightly irregular pancreatic veins in one patient with a malignant glucagonoma. Theoretically this finding could be due to a pharmaco-angiographic effect of glucagon, but in 2 other patients with glucagonoma pancreatic phlebography appeared normal.

Pancreatic phlebography was useful in the differentiation between pancreatic and extrapancreatic disease. In patients with cholangiocarcinoma the veins of the pancreas usually were patent and normal arguing against a large pancreatic carcinoma. In one case occlusion, and in 2 cases stasis of the choledochal veins could be demonstrated.

In a patient with malignant lymphoma in the region of the pancreas, phlebography was of value to rule out a pancreatic carcinoma suggested from a mass lesion found at laparotomy. Furthermore, the percutaneous aspiration biopsy was successfully guided by phlebography. However, angiography in this case offered similar information and the biopsy could have been performed in combination with any other diagnostic method able to localize the lesion.

Conclusions

1) Selective phlebography gave indication of carcinoma in 21 of 35 cases.

2) The minimum size of demonstrable tumours was 3 to 4 cm.

3) Differentiation between carcinoma and chronic pancreatitis is possible, although of minor clinical value.

4) Evaluation of venous morphology is without value in patients with islet cell tumours.

5) Differentiation between pancreatic and peripancreatic disease is possible but of no clinical importance.

SUMMARY

Pancreatic phlebography was performed in 67 patients with proven inflammatory or tumour disease in the region of the pancreas. The findings are described and the diagnostic value of the method is discussed.

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PERCUTANEOUS TRANSHEPATIC PORTOGRAPHY IN PANCREATIC CARCINOMA

Diagnosis and evaluation of resectability

W. REICHARDT and I. IHSE

The prognosis for patients with pancreatic carcinoma is poor. The results of pancreatico-duodenectomy according to Whipple have been discouraging (FOSTER et coll. 1967). Therefore, a renewed interest in total pancreatectomy has arisen and promising results have recently been reported (BROOKS & CULEBRAS 1976, IHSE et coll. 1977). Only surgery may cure patients with pancreatic malignancy. However, a proper selection of patients is necessary as radical surgery is not meaningful once the tumour has grown outside the pancreas (IHSE et coll.). Current diagnostic methods, such as ultrasound, computer tomography, scintigraphy endoscopic retrograde cholangiopancreaticography (ERCP), percutaneous transhepatic cholangiography (PTC) and angiography, have increased the possibilities of making an accurate preoperative morphologic diagnosis (OKUDA et coll. 1974, GOLDSTEIN et coll. 1974, CLASSEN et coll. 1975, SHEEDY et coll. 1977, HUSBAND et coll. 1977, TRILLER 1978).

Previously SUZUKI et coll. (1972) and TYLÉN & ARNESJÖ (1973) found a correlation between angiography (extent of arterial involvement) and operability and survival time. BURANASIRI & BAUM (1972) and others have emphasized the importance of the venous phase of coeliac and superior mesenteric angiography in the evaluation of pancreatic carcinoma. Contrast enhancement is improved in direct portography compared with the venous phase of angiography and more detailed information about morphologic abnormalities is thus obtained.

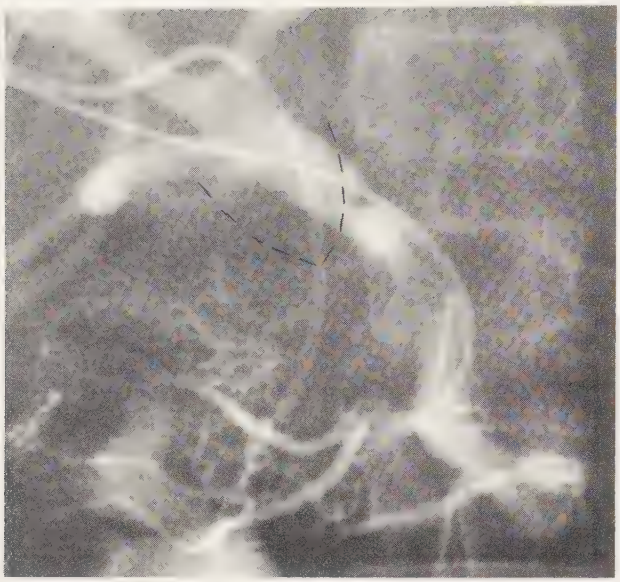
The results of percutaneous transhepatic portography (PTP) and selective phlebography of the pancreatic veins in pancreatic carcinomas have been compared with the findings at angiography. Special attention was paid to the diagnostic accuracy and prediction of resectability of the lesions.

Material and Methods

During 1973 to 1978, 35 patients with microscopically confirmed carcinoma of the head of the pancreas were examined with percutaneous transhepatic portography and selective phlebography of the veins of the head of pancreas at this Department of Diagnostic Radiology. As the methods and criteria for evaluation have been described in detail elsewhere (GÖTHLIN et coll. 1974, REICHARDT et coll. 1978) only a brief summary is now given. The portal vein was punctured using a 25 cm long needle coated with a polyethylene catheter (OD 1.6 mm, ID 1.0 mm, Surgimed, Denmark). Contrast medium was injected with the tip of the catheter placed in the superior mesenteric vein. In cases involving the confluence, the splenic vein was also examined. Forty ml of Isopaque Coronar, 370 mg I/ml (Nyegaard, Norway) was injected at a rate of 8 ml/s; 16 films were exposed (5 films/5 s, 8 films/4 s, 3 films/6 s). After selective catheterization of the pancreatic veins 8 films were exposed (2 films/s) after injection of 2 to 10 ml of contrast medium. The amount of contrast medium was adjusted to the size of the vessel and the injection was made by hand.

In 33 of the patients a selective angiography was

Submitted for publication 31 May 1979.



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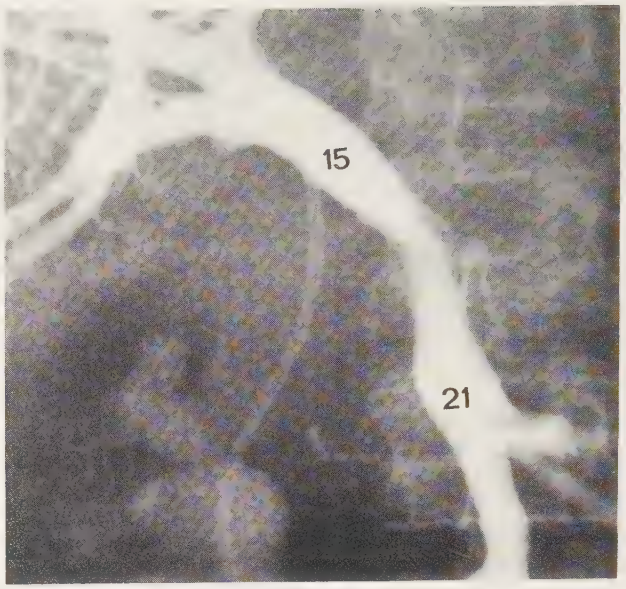

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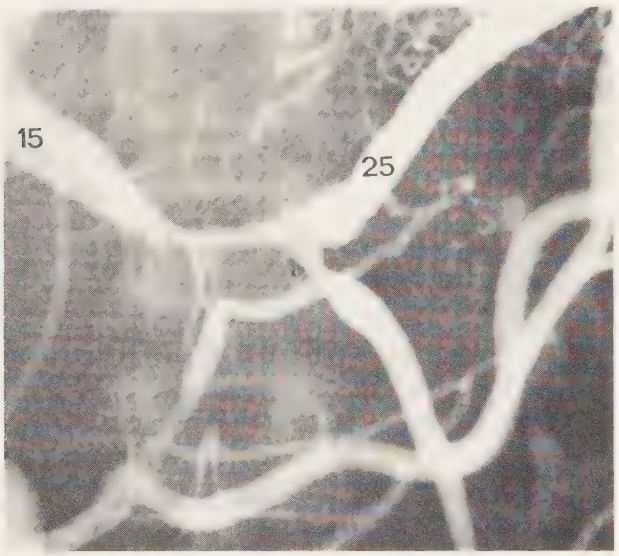

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Fig. 1. Carcinoma of the head of the pancreas. a) Selective phlebography of the anterior superior pancreaticoduodenal vein. Occlusion of the veins of the head. The lines represent the shape of the obstructed common bile duct at PTC. b) PTP. Injection into the superior mesenteric vein. Stenosis of the confluence with a pressure gradient of 6 cm H_2O. c) PTP. Injection into the splenic vein. Stenosis of the confluence with a pressure gradient of 10 cm H_2O. The tumour was not resectable.

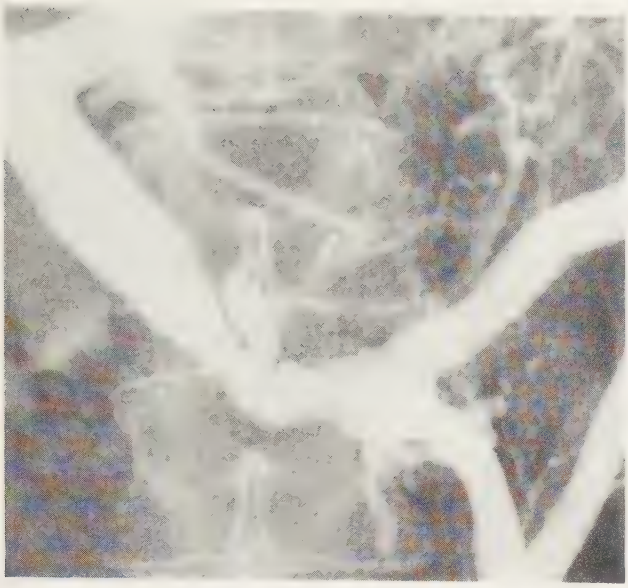
performed including injection into the coeliac and superior mesenteric arteries. In 31 patients 25 mg Tolazolin was injected directly into the superior mesenteric artery immediately before the injection of contrast medium in order to improve filling of the veins. The criteria for evaluation of the angiographic findings were those described previously (LUNDERQUIST 1965, BOOKSTEIN et coll. 1969, BURANASIRI & BAUM) and include: Arterial displacement, arterial stenosis and occlusion, tumour vessels, accumulation of contrast medium within the tumour, venous displacement, and venous stenosis and occlusion.

In 34 of the patients obstructive jaundice was the main symptom and percutaneous transhepatic cholangiography was performed before angiography and portography. One tumour was detected at elective cholecystectomy. In 30 patients extirpability of the tumour was estimated at laparotomy and the find-

Table 1

Radiologic diagnosis in 33 patients with pancreatic carcinoma

	Carcinoma	Suggestion of carcinoma	Pancreatitis	Atheromatosis	Postoperative abnormalities	Normal	No adequate examination
Angiography	28	0	0	2	1	2	0
Selective phlebography	21	4	3	0	0	0	5



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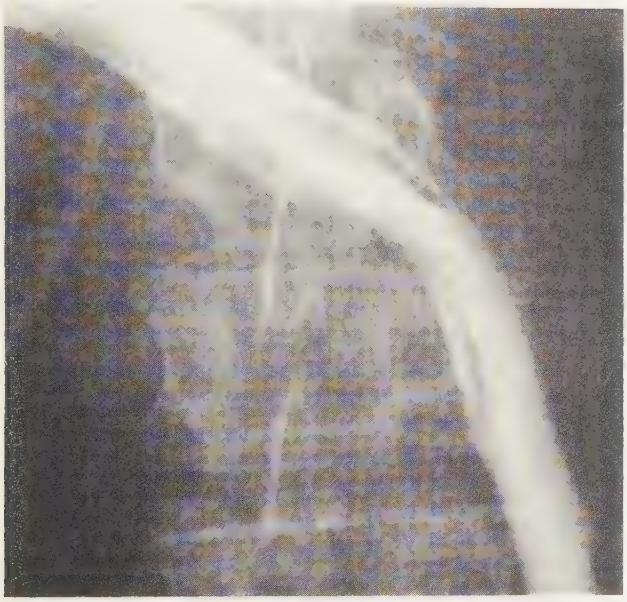

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Fig. 2. PTP in three patients with carcinoma of the head of the pancreas. Varying extent of venous involvement was observed. a) Circular stenosis of the portal vein, confluence and splenic vein with irregularity of the wall of the vessels. b) Marked stenosis of the superior mesenteric vein close to the confluence. c) Impression of the superior mesenteric vein, slight stenosis.

ings were compared with those obtained at angiography and phlebography. In 2 patients the radiologic results were compared with autopsy findings one and two months after examination, respectively. One 70-year-old patient was not operated upon but palliated with a transhepatically applied endoprosthesis.

Results

Angiography. In 28 of the 33 patients the tumour diagnosis was made at angiography (Table 1). Arterial encasement limited to small intrapancreatic arteries or tumour vessels was evident in 12 patients and in 11 the gastroduodenal artery was also involved. Encasement of other extrapancreatic arteries was found in 5 patients and, in addition, 2 had liver metastases.

Evaluation of the venous phase of the angiography disclosed venous lesions in 7 patients while in 3 venous involvement was suggested. In 4 cases no adequate venous filling was obtained.

In 5 patients the diagnosis of tumour was not made at angiography. No abnormality was found in 2. In 2 patients the vascular abnormalities were erroneously considered as atheromatosis and in both selective phlebography indicated tumour growth. In one patient stenosis of the gastroduodenal artery was the only finding but was not of diagnostic value because of previous resection of the stomach. Selective phlebography disclosed abnormalities suggestive of pancreatitis. The patient died 2 months after angiography and a tumour 2 cm in diameter at the papilla surrounded by pancreatitis was found at autopsy.

Portography and selective phlebography. In 21 of the 33 patients correct diagnosis was made at selective pancreatic phlebography (Fig. 1) and in 4 the veins of the head of the pancreas were found to be

a b

Fig. 3. Carcinoma of the head of the pancreas. At angiography indication of non-resectability. a) Venous phase of angiography considered as normal. b) PTP revealed impression of the superior mesenteric vein. At surgery a tumour 5 cm in diameter was resected, radicality was doubtful. Lymph node metastases were present.

obliterated, suggesting tumour growth (Table 1). In 3 cases the veins of the head were irregular, slender and either stretched or tortuous indicating pancreatitis (REICHARDT et coll., REICHARDT, to be published). In 2 cases the selective phlebography could not be evaluated due to extravasation of contrast medium and in 3 due to inadequate filling of the pancreatic veins.

Infiltration of the superior mesenteric vein, portal vein or confluence was found in 4 patients. Criteria for infiltration were circular stenosis with irregularity of the wall of the vessels (Fig. 2) or tumour thrombus. A marked stenosis in 12 cases indicated tumour growth adjacent to the vessel.

Smooth local impression of the vein was found in 7 cases, in 2 the involvment of the veins was doubtful. In 8 cases no involvement of the portal, the superior mesenteric or the splenic vein was found.

Evaluation of resectability. Including patients with encasement of the gastroduodenal artery 19 tumours were regarded as non-resectable at angiography. In spite of this, resection was performed in 4 of these cases but in 3 surgery was not radical and the patients died within 6 months after surgery. One patient, in whom radicality was doubtful, died 10 months after resection. No recurrence was found at autopsy.

The portography revealed venous involvement in 23 patients. Five of these tumours were resected but in 3 instances not radically. In 2 patients with tumours of about 5 cm diameter resection was performed with doubtful radicality (Figs 3, 4). In these 5 patients the resection was difficult and the blood loss during operation marked. All patients died within 20 months after surgery.

In all cases the portography demonstrated the morphologic abnormalities of the portal system more distinctly than did the venous phase of superior mesenteric angiography (Fig. 5). In 12 cases the portography disclosed involvement of the portal system undetected at angiography. In 4 of these 12 cases non-extirpability was already indicated by encasement of extrapancreatic arteries or liver metastases. In an additional 3 patients the gastroduodenal artery was encased. In 5 patients the involvement of

a

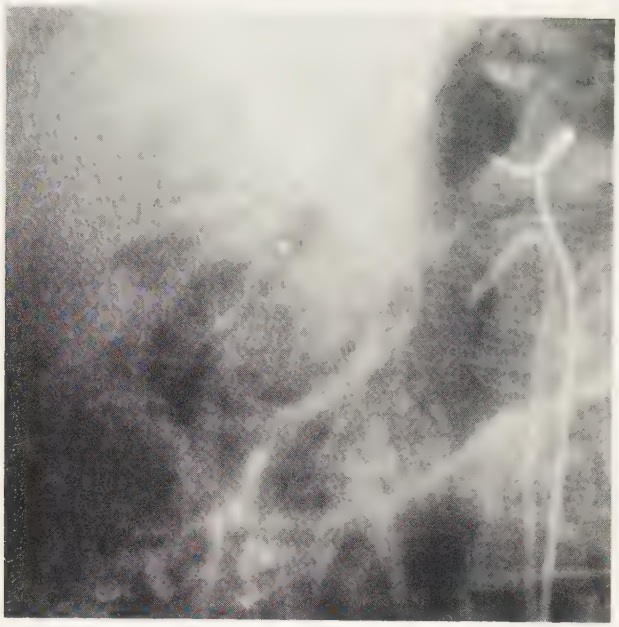

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Fig. 4. Carcinoma of the head of the pancreas. a) Simultaneous coeliac and superior mesenteric artery injection. Stenosis of the smaller pancreatic arteries. Short, slight stenosis of the gastroduodenal artery at its origin. b) Venous phase of angiography. No venous involvement. c) PTP. Slight impression of the superior mesenteric vein. At surgery a tumour 5 cm in diameter was resected, radicality was doubtful.

the veins demonstrated at portography was the only sign of non-extirpability.

Discussion

For diagnosis of a pancreatic carcinoma several methods are available, such as ultrasound, computer tomography, scintigraphy, ERCP, PTC and angiography. In the majority of patients the diagnosis can be cytologically confirmed by fluoroscopically guided fine-needle biopsy (TYLÉN et coll. 1976, HAAGA & ALFIDI 1976, HO et coll. 1977, GOLDSTEIN et coll. 1978, EVANDER et coll. 1978). As most of the patients with carcinoma of the head of the pancreas are admitted with obstructive jaundice, transhepatic cholangiography combined with fine-needle aspiration biopsy is the first diagnostic step at this hospital. As soon as the diagnosis of a carcinoma is established it is of importance in planning the treatment to determine the extent of the tumour and its extirpability. The size of the tumour can be estimated by ultrasound, computer tomography and angiography and these methods are also useful for the detection of liver metastases. As invasion of the large vessels adjacent to the pancreas is a limiting factor for radical surgery, angiography and portography should be the proper method to evaluate the extirpability preoperatively. A clear correlation between angiographic findings, operability and survival time has been demonstrated (SUZUKI et coll., TYLÉN & ARNESJÖ). In order to improve the results of radical surgery, a careful selection of patients based on a proper preoperative evaluation of the extirpability of the pancreatic carcinomas is of utmost importance.

Previously, it has been suggested that involve-

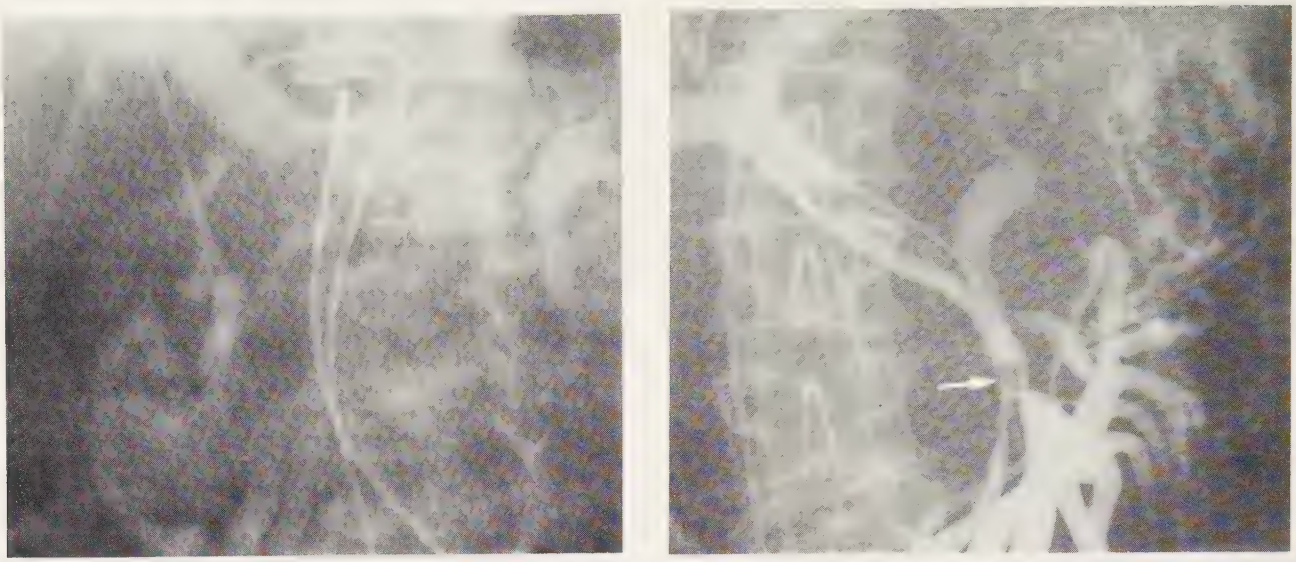

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Fig. 5. Carcinoma of the head of the pancreas. a) Venous phase of superior mesenteric artery injection. Compression of the confluence, dilated tributaries of the superior mesenteric vein. b) PTP. Injection into the superior mesenteric vein revealed displacement of the vein, marked stenosis and thrombus (→).

ment of extrapancreatic arteries is indicative of non-extirpability of the tumour. SUZUKI et coll. found that even encasement of the gastroduodenal artery or several intrapancreatic arteries indicates inoperability.

TYLÉN & ARNESJÖ found in 26 patients with involvement of the gastroduodenal artery only 6 resectable tumours and none of these 6 patients lived more than 12 months. In the present series 11 patients had encasement of the gastroduodenal artery. In 2 of these the tumours were resected; in one case the resection was not radical and the patient died 6 months after surgery. The other patient had a very slight stenosis of the gastroduodenal artery at its origin (Fig. 4), possibly caused by atheromatosis. These findings argue for non-resectability in cases with obvious tumour encasement of the gastroduodenal artery. It has not been reported to date if encasement of the main stems of the portal vein system is a reliable indication of non-extirpability. In most of the present patients involvement of the large veins was combined with abnormalities indicating non-resectability at angiography such as encasement of the gastroduodenal artery or other extrapancreatic arteries. In 7 patients (Table 2) with venous involvement without arterial abnormalities indicating non-extirpability the tumour was regarded in 4 as non-resectable at laparotomy. Three of these patients were operated upon with resection. In 2 the resections were not radical and in one radicality was doubtful and, furthermore, lymph node metastases were present.

Surgery was not radical in any patient with evi-

Table 2

Carcinomas of the head of the pancreas with venous involvement but without arterial abnormalities indicating non-resectability

Case	Portography	Angiography, venous phase	Surgical findings
1	++	+	Tumour of about 10 cm diameter, not resectable
2	++	(−)	Not resectable, liver metastases
3	++	−	Tumour of 4 cm diameter, resection not radical
4	++	−	Not resectable
5	+	(+)	Tumour of 2.5 cm diameter, resection not radical
6	+	−	Movable, liver metastases
7	+	−	Tumour of 5 cm diameter, resected, radicality doubtful, lymph node metastases

++ stenosis
\+ impression or displacement
(+) uncertain involvement
(−) no adequate filling
\- no abnormality

dent involvement of the veins. In all cases with minor displacement of the vessels in which resection was performed, the operations were technically difficult and complicated by intraoperative bleedings. In 2 of 5 cases surgery was regarded as radical but with small margin (2 mm). These results suggest that patients with stenosis of the main stems of the portal vein system are not suitable candidates for radical surgery. This contradicts the results of MARIONS (1974) who reported at least 2 cases with stenosis of the veins in which resection was considered radical. If a localized impression of the portal vein is observed at portography, radical surgery may be attempted but the procedure may be technically difficult.

The present results indicate the usefulness of portography in the evaluation of resectability of pancreatic carcinoma. The method should be used as a supplement in patients in whom angiography does not give unequivocal information about non-resectability.

Resection of tumours encasing the gastroduodenal artery was formerly regarded as worthwhile in low risk patients (TYLÉN & ARNESJÖ). As regional intraarterial infusion of cytotstatics has been reported to diminish pain (GAZET 1973) palliative resection no longer seems to be motivated, further emphasizing the need for a proper preoperative evaluation of resectability.

The diagnosis of pancreatic carcinoma can be made at selective phlebography of the pancreatic veins. However, in most cases, the diagnosis is easier to obtain with other, less invasive methods and phlebography cannot be recommended for diagnostic routine use. A number of cases will still remain where the differentiation between carcinoma and pancreatitis is difficult and in these cases selective phlebography of the pancreatic veins can be of value (REICHARDT et coll., REICHARDT).

SUMMARY

In 33 patients with carcinoma of the head of the pancreas, both angiography and percutaneous transhepatic portography combined with selective phlebography of the pancreatic veins were performed. The tumour diagnosis was made in 28 patients by angiography and in 21 by phlebography. Correlation was found between extrapancreatic artery encasement, involvement of the main stems of the portal vein system and non-resectability of the tumour. In 5 patients venous involvement demonstrated by portography was the only indication of non-resectability of the tumours.

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